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Water Plant Optimization Study

LONDON-LAKE HURON AREA WATER SUPPLY SYSTEM

December 1990

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Water Plant Optimization Study

London

Lake Huron Area Water Supply System

Project No. 7-2024

December 1990

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

1.0 INTRODUCTION

This report on the London (Lake Huron) Water Treatment Plant Optimization Study was prepared by MacLaren Engineers Inc. on behalf of the Ontario Ministry of the Environment under Agreement dated October 26, 1987.

The project is a result of the Drinking Water Surveillance Program (DWSP) being carried out by the Ministry of the Environment on municipal water supplies. Under this program, which began on April 1, 1986, a continuously updated base of information is being established on Ontario water plants and water quality. The Water Plant Optimization Study (WPOS) program was initiated for each plant entering the program in order to complement the data generated from the Drinking Water Surveillance Program.

Terms of References for the Water Plant Optimization Study were prepared by the Ministry of the Environment. The purpose of the study is to document and review present conditions and determine an optimum treatment strategy for contaminant removal at the plant, with emphasis on the removal of particulate materials and disinfection processes. To maintain a current database of information, it is envisaged that the WPOS report will be updated on an annual basis.

As a supplement to the Water Plant Optimization Study for the London (Lake Huron) Water Treatment Plant, a separate report was prepared on the existing waste management practices at the plant. The report provides an overview of the existing treatment facilities and includes sections on sources of wastes, waste characteristics, present disposal practice and estimates of capital and operating costs for the existing treatment works. The report was prepared by MacLaren Engineers Inc. for the Ministry of the Environment under the title: Wastewater Disposal Study, London (Lake Huron) Water Treatment Plant, August, 1988.

2.0 HIGHLIGHTS OF STUDY

2.1 Raw Water Quality

The London (Lake Huron) Water Treatment Plant is located on the shoreline of Lake Huron about 1.6 km north of the Village of Grand Bend.

Raw water is drawn from Lake Huron through an octagonal-shaped intake crib and 1830 mm diameter concrete pressure pipe. The crib is located 2530 m off-shore in 15.2 m of water (at average lake level) and has an average depth of submergence of 8.8 m.

The lake water is generally of good quality with the exception of the occurrence of seasonally high raw water turbidity (>100 FTU) and summer algae blooms. Monthly average turbidity levels vary from 2.0 FTU to about 22 FTU.

Blooms of diatom plankton occur each year in the spring and fall when the lake water temperature is between 10 and 15°C. The range in monthly average algae densities is from 1 to 1999 A.S.U. per mL; whereas the two-year average (during the study period) was determined as 542 A.S.U. per mL.

Chemical water quality data evaluated showed that the lake water has the following characteristics: pH generally above 8.0 units (range 7.5 to 8.7); alkalinity varies from 78 to 97 mg/L as $CaCO_3$; total hardness varies from 92 to 106 mg/L as $CaCO_3$.

Bacteriological test data for total and fecal coliform organisms and fecal streptoccus revealed that the lake water is contaminated with matter of fecal origin and is unsafe for direct consumption without proper treatment and disinfection. The levels of fecal coliform encountered vary from 6 to 10 organisms per 100 mL, while the densities of fecal streptoccus are 10 to 15 times higher.

2.2 Flow Measurement Accuracy

The majority of primary flow elements consist of magnetic flow meters (raw and treated water flow, service water, sludge, and filter backwash water). Filter effluent meters are of the short form Venturi tube-type, and the meter on the treated water supply to Grand Bend is a mechanical compound water meter.

The raw water magnetic flow meters are no longer sufficiently accurate and, therefore, are not used for monitoring purposes. The two treated water flow meters (on the London pipeline) are considered to be quite accurate as they are hydraulically flow tested periodically by pumping up the Ausable Reservoir located mid-way on the pipeline. These meters are therefore used for monitoring treated water flow and for control of chemical feed rates. Raw water flow is established indirectly from treated water flow using back-calculations.

2.3 Plant Capacity and Process Design

The Lake Huron Water Supply System Water Treatment Plant was constructed from 1966 to 1967 with a design capacity of 336,400 m^3/d. Initially, the capacity was limited to 168,200 m^3/d by the capacity of the treated water pumps but following construction of the Ausable Booster Pumping Station in 1977, the design capacity of 336,400 m^3/d was established.

The original plant was designed for direct filtration which included rapid mixing, two-stage flocculation, and dual-media filtration. This process worked well with good raw water quality. Levels of high turbidity or high algae densities would limit plant production down to flows of 136,000 m^3/d. This problem was eliminated by the installation of parallel plate clarifiers in 1985 to 1986. At this time also, facilities were installed for the treatment and land disposal of settled sludge.

2.4 Process Automation

The original plant was equipped with a complete analogue supervisory and control system whereby plant operations could be controlled either automatically or manually. A microwave radio telemetering system was installed to enable communications between the plant, the Arva Terminal Reservoir in London, and the mid-line Ausable Reservoir and Pumping Station.

During the recent plant expansion and upgrading, new automatic control equipment was installed for sludge recirculation pumps and sludge wasting pumps, as well as for polymer feed systems. All systems were designed to accept the future addition of a computer for plant control.

2.5 Plant Operations

The plant is operated on the basis of remote manual and local manual control modes, except for low lift pumps and filters which are operated automatically most of the time.

Two operators are on duty during the day shift and one operator mans the night shift. During the day, one operator will staff the Control Room while the other monitors plant operations, carries out water quality tests, sets chemical feed rates, confirms the accuracy of on-line monitors, is in charge of chemical deliveries, and backwashes filters.

2.6 Process and Quality Control

The plant operator is responsible for process and quality control, and maintains the Daily Log Sheet. Chemical water quality testing is done by the operator in the plant laboratory, whereas water examination for bacteriological and biological parameters is done routinely at the M.O.E. laboratories.

3.0 PLANT PERFORMANCE

3.1 Particulate Removal

Treated water quality during the study period has consistently met the established Ontario Drinking Water Objective of 1.0 FTU for turbidity.

With conventional treatment (November 1986 to 1987), daily average treated water turbidities ranged from 0.08 to 0.18 FTU and the average was 0.14 FTU. Minimum and maximum values recorded were 0.05 and 0.31 FTU respectively.

Somewhat higher levels and greater variations in treated water turbidity occurred with direct filtration. Daily averages typically ranged from 0.20 to 0.30 FTU, and daily maximums of over 0.50 FTU were not uncommon. Minimum and maximum values recorded were 0.07 and 0.84.

The length of filter runs averaged 66 hours with conventional treatment and 34 hours with direct filtration. In the case of the latter process, filter run times were significantly lower than the average during the presence of high raw water turbidity or high levels of algae.

3.2 Disinfection

Prechlorination was practiced at an average dosage of about 0.73 mg/L chlorine which resulted in an average free chlorine residual after the filters of 0.52 mg/L over the study period. The chlorine contact time at the design flow rate is in the order of 4 hours. This long contact time is beneficial to the disinfection process but sometimes provides increased opportunities for the formation of trihalomethanes (THMs). The levels of total THMs formed at the Lake Huron plant are very low, and, according to MOE DWSP test results, ranged from 29.0 to 40.8 µg/L in 1986 to 1987.

Postchlorination is applied at the inlet to the Clear Well which, at the design flow rate, has a theoretical detention time of 28 minutes. The contact time increases to more than 9 hours during delivery of the water to London.

During the study period, the average postchlorine dosage applied was 0.90 mg/L (range of 0.31 to 1.80 mg/L), which resulted in an average total chlorine residual of 1.0 mg/L (range of 0.29 to 1.33 mg/L).

Based on the bacteriological test results for raw and treated water, it was concluded that the disinfection practice at the Lake Huron Water Treatment Plant was very efficient and that no immediate improvements need to be made to the process. A downward adjustment of the high raw water pH during the summer could be considered to improve the efficiency of disinfection, although the inefficiency at high pH appears to be more than compensated for by the long contact times available in pre- and postchlorination.

3.3 Taste and Odour Control

Treated water is informally examined by the operator for objectionable taste and odour by simply sniffing and tasting the water. Although no problems were reported for the study period, some taste and odour problems did occur in the past on a seasonal basis during periods when the raw water contained elevated levels of algae. This problem was corrected by discontinuing prechlorination during the summer months.

3.4 Aluminum and Iron in Treated Water

The average dissolved aluminum content in the treated water was 0.063 mg/L in 1987, 0.053 mg/L in 1986, and 0.059 mg/L in 1985, and varied from not detected to 0.23 mg/L over the three years. For the same period, the treated water pH had an average value of 7.69 units and the range was 6.87 to 8.12 units.

In comparison to other treatment plant outputs the dissolved aluminum residuals were quite low and are less than the equilibrium value of 0.27 mg/L theoretically attainable in a pure system at pH of 7.7 units (Amirtharajah and Mills, 1982 after Rubin & Kovac, 1974).

The residual iron concentrations are also very low, ranging from not detected to 0.18 mg/L with an average of 0.017 mg/L. Such low dissolved iron residuals are to be expected since the solubility of iron hydroxide species is very low at the treated water pH values experienced at this facility.

3.5 Stability of Water

On the basis of the Langelier Saturation Index it was determined that the water is slightly aggressive after treatment.

4.0 RECOMMENDATIONS

4.1 Physical Improvements

No physical improvements need to be undertaken at this time to improve operations at the London (Lake Huron) Water Treatment Plant with respect to particulate removal and disinfection.

4.2 Studies

1. Primary and Secondary Coagulant Evaluation

   Continue jar testing, followed perhaps by additional pilot plant and plant scale testing, to determine best primary coagulant for use in the conventional treatment mode and with difficult-to-treat water containing colloidal turbidity. Determine the benefits, if any, of secondary coagulants, and define the best order of addition if a combination of chemicals is chosen.

2. Coagulant Dosage Control

   Evaluate the use of a feedback controller whereby the Streaming Current Detector's output signal can be used to automatically adjust coagulant dose.

3. Optimization of Coagulation Process

Carry out studies to establish whether downward adjustments of the raw water pH (in the range of 6.0 to 7.0) would be beneficial in the optimization of the performance of the coagulation process. Re-adjustment of treated water pH, of course, would be necessary for stability control. It is noted that a caustic soda dosing system was installed during the recent plant expansion which may be suitable for use with the proposed system for optimization of the coagulation process.

4. Addition Point of Chemicals

Investigate changing the point of coagulant addition near the hub of the impeller in the rapid mix tanks. Install additional points in both chambers of each reactor if sequencing of the addition of two coagulant chemicals is found to be important.

5. Seasonal Energy Input Adjustment

Investigate adjusting the input energy to the chemical flocculators from season to season to allow for differences in flow and water temperatures.

Also investigate benefits to be achieved from using tapered flocculation with the conventional treatment process.

6. Filter Aid

Determine the benefits of adding a filter aid to the settled water prior to filtration. Investigations could be carried out by pilot or full scale testing.

7. Filter Operation

a) Slow Start-up

Investigate the effect of a slow start-up of a filter at uniform rate over a 10 to 30-minute period on performance during the filter ripening sequence.

If successful, then it is recommended that this mode of filter start-up operation be included in the impending computerization studies for the Lake Huron plant.

b) Conditioning of Backwash Water

Carry out studies to establish the effectiveness of preconditioning a filter during the backwash using a metal salt or polymer coagulant to reduce the level and duration of increased effluent turbidity during the filter ripening sequence.

c) Filter to Drain

An alternative method of conditioning a filter to improve effluent turbidity during start-up is to filter to drain. The magnitude and duration of the filter ripening sequence should be investigated to determine whether this option is feasible. This procedure could be investigated, at reduced filter rates, using the manually controlled filter drain pipe.

d) Filter Rest Period

Investigate a practice of allowing a backwashed filter to rest at least 15 minutes before reinstatement into service.

The capability of delaying the start-up of a filter after a backwash should be considered during the plant's instrumentation study.

4.3 Short-Term Modifications

1. Raw Water Flow Meters

The raw water flow meters including the primary sensing elements should be flow-tested and re-calibrated so that accurate flow measurements can be made and recorded, and to ensure that the best control signals possible exist for pacing of chemical metering pumps.

2. Low Lift Pumping Station

Install a permanent dewatering pump, adequately sized, in the surge well.

3. Alum Storage Tanks

Provide new sonic level sensing instruments with indicating transmitters for signal transmission to recorders to be located in the Main Control Room.

4. Chlorine Weigh Scale

Replace the existing weigh scale with three new electronic scales, one each for prechlorination and postchlorination service and one in reserve, complete with electronic instrumentation and signal transmission to the control room.

5. Filters

All filter instrumentation and control systems will be replaced under the upcoming computerization contract.

To permit monitoring of filter effluent turbidity from individual filters, new on-line turbidity meters with recorders should be installed on all filters.

6. Power Supply

Requirements for standby power at the plant should be investigated. There should be sufficient capacity in emergency power to operate various pumps and auxiliary equipment to sustain the average day plant production at about 160,000 m^3/d.

7. Water Quality Examination

Existing programmes for the examination of raw and treated water quality should be continued. This should include the programme for monthly algae analysis.

In addition, the DWSP should be continued whereby the water is examined for many parameters including toxic and potentially toxic organic chemicals which may adversely affect health. The program should be expanded to include two or three sample locations in the London distribution system.

4.4 Long-Term Modifications

1. Plant Hydraulic Distribution Study

Conduct a tracer study to evaluate the distribution of flow to all parallel unit operations, and to determine the extent of short circuiting in each. Determine whether corrective measures need to be taken.

2. Corrosiveness of Plant Effluent

Establish the corrosiveness of the treated water, using such methods as coupon testing, and determine the level of pH adjustment, or any other measures, that need to be implemented in order to control the potential aggressiveness of the treated water.

ACKNOWLEDGEMENTS

Members of the Project Committee for the London (Lake Huron) Water Treatment Plant are listed on the fly-sheet of this report. The cordial assistance provided by each of these members during the course of this study is hereby gratefully acknowledged. To all others who have assisted us in any way, we express our sincere thanks.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols Used

d	day
h	hour
min.	minute
s	second
m	metre
mm	millimetre
cm	centimetre
m^2	square metre
m^3	cubic metre
L	litre
mL	millilitre
kg	kilogram
mg	milligram
g/L	microgram per litre
L/h	litre per hour
L/min.	litre per minute
L/s	litre per second
m/s	metre per second
m/h	metre per hour (filter rate or surface overflow rate equal to $m^3/h.m^2$)
m^3/d	cubic meter per day
kg/h	kilogram per hour
°C	degree Celcius
FTU	Formazin turbidity unit
NTU	Nephelometric turbidity unit
ACU	apparent colour unit
TCU	true colour unit
A.S.U. per ml	areal standard units per millilitre (ASU/mL)
s^{-1}	mean velocity gradient, metre per second per metre
rpm	revolution per minute
V	volt
A	ampere
kVA	kilovolt ampere
kW	kilowatt
>	greater than
<	less than
%	per cent

Abbreviations Used

DWSP	Drinking Water Surveillance Program
MOE	Ontario Ministry of the Environment
WPOS	Water Plant Optimization Study
Al	aluminum
Alum	aluminium sulphate
A.S.U. per mL	areal standard units per millilitre
$CaCO_3$	calcium carbonate
Cl_2	chlorine
N	nitrogen
NH_3	ammonia
SO_2	sulphur dioxide
PACl	polyaluminum chloride
E.S.	effective grain size
U.C.	uniformity coefficient
L.I.	Langelier Saturation Index
MF	membrane filter technique for enumerating bacteria in water
pH	expresses the intensity of the acid or alkaline condition of a solution
p.f.	power factor
SWD	side water depth
THM	Trihalomethane
TTHM	total trihalomethane

INTRODUCTION AND TERMS OF REFERENCE

INTRODUCTION AND TERMS OF REFERENCE

1. BACKGROUND

The Ontario Ministry of the Environment has instituted a Drinking Water Surveillance Program. The Program began on April 1, 1986 and encompasses all municipal water supplies in Ontario. The primary objectives of the DWSP for Ontario are to establish a reliable database on water quality which will encompass a wide range of parameters, including pesticides and organic compounds, and to maintain information current by continuously updating the database. In connection with the DWSP, a plant investigation and process evaluation study (WPOS) is initiated for each plant entering the program. A major goal of the Water Plant Optimization Study is to document information on the plant's process design and operations, and to determine an optimum treatment strategy for contaminant removal at the plant. It is intended to update the study on an annual basis in order to maintain the database current. The information from these studies will allow valid water quality data to be collected. The results will further identify potential problem areas, serve as the basis for remedial action, and provide a framework for defining contaminant levels and trends.

2. TERMS OF REFERENCE

A detailed protocol for the Water Plant Optimization Study has been prepared by the Ministry for use by the consultants engaged for the optimization studies. This study of the London (Lake Huron) Water Treatment Plant has been conducted in accordance with the protocol. The main objective of the plant investigation and process evaluation study is:

> *"To review the present conditions and determine an optimum strategy for contaminant removal at the plant, with emphasis on particulate materials and disinfection processes."*

To meet this objective, Terms of Reference were prepared by the Ministry (Rev. 1, 06/04/87 attached - Appendix D) consisting of eight specific work tasks which require the consultant to examine, in

detail three years of daily and monthly operating data, to prepare a comprehensive assessment of plant operations and the level of performance achieved, and to provide recommendations for short and long term modifications in order to obtain optimum disinfection and contaminant removal.

As a supplement to the Water Plant Optimization Study, the consultant was commissioned to prepare a separate report on the handling and disposal of wastewaters generated at the plant.

3. LAKE HURON WATER SUPPLY SYSTEM

The London (Lake Huron) Water Treatment Plant is owned and operated by the Ontario Ministry of the Environment to supply drinking water to the City of London and various communities located near the plant and along the 48 km long pipeline to London. The additional communities being served include the following:

- Villages of Grand Bend, Aisla Craig, East Williams, West Williams, Thedford and Ilderton

- Town of Parkhill

- Townships of McGillivray, London (Denfield), Stephen, Bosanquet and Hay.

The total population served is in the order of 300,000. For a breakdown of the population by service area reference is made to Section B.3. Also, per capita water consumption data for 1985 to 1987 have been summarized in Table 1.1 of Appendix C.

The treatment plant was originally designed and constructed as a direct filtration plant. Treatment processes for particulate removal consisted of flash mixing, flocculation, and dual-media filtration. In 1985 to 1986 the plant was expanded and upgraded. Sedimentation facilities were added to ensure the plant's capability to treat water at the

design flow rate under all raw water quality conditions. In addition, facilities were added for the treatment and disposal of settled solids from the clarifiers.

Plant staff, under the direction of the superintendent, will respond to accidents involving hazardous chemicals. Reference material available on the various chemicals, consists of the WHIMS fact sheets but no formally documented emergency-response plan exists at this time. The Ministry's Operations Division of the Southwest Region is considering the preparation of such an emergency-response plan in the coming years.

After the experience of a previous pipeline break, a plan was developed to ensure the security of supply to London by entering into agreements with:

- the London Public Utilities Commission, who would provide the emergency repair crew

- five local contractors who could be called upon to respond with heavy construction equipment and operators.

In addition, spare concrete pressure pipe and repair couplings (12 standard lengths of pipe and 4 repair couplings) are being stocked at the plant.

Plant security measures comprise security fencing around the entire site and locked outside plant doors. The keying system for these doors is changed every five years. Under the upcoming computerization contract for the plant, an electronic security alarm and surveillance system will be provided. This system will include alarms on doors, motion detectors, and exterior, fence-mounted video cameras.

SECTION A
RAW WATER SOURCE

SECTION A - RAW WATER SOURCE

A.1 SOURCE

The London (Lake Huron) Water Treatment Plant is located on the shoreline of Lake Huron, in Stephen Township, County of Huron, near the Village of Grand Bend. Water is drawn from the lake via a 1830 mm diameter reinforced concrete pressure pipe extending some 2530 m into the lake. The octagonal-shaped intake crib, constructed of fabricated steel, is located in 15.2 m of water at average lake level and has a depth of submergence of 8.8 m.

A.2 QUALITY

Lake Huron water in the region of the Plant intake generally is of good quality with the exception of raw water turbidity which can exceed 100 FTU and summer algae blooms. Extensive records are being kept by the plant. Those for the period 1985 to 1987 are presented in the protocol tables for the Optimization Study attached to the end of this report. A summary of the data for several parameters is presented in Table A.1 to express general water quality conditions. A more detailed discussion of various water quality parameters follows.

a) Physical Parameters

Turbidity: The average monthly turbidity varies from a low of 2.0 FTU to a high of about 22 FTU. Greater fluctuations occur in daily values which vary from less than 1.0 FTU to 140 FTU. The overall average for the three-year record is 9.0 FTU. Except for July and August, the higher values of turbidity have been encountered during each month of the year, and are the result of turbulence in the lake caused by wind action and turbid spring runoff.

Temperature: Raw water temperature is measured once per day at the plant. Daily temperature extremes during the year range from 3°C to 22°C. The yearly average temperature is in the order of 11°C.

Taste and Odour: Taste and odour tests are not performed regularly but during June, July, and August prechlorination is discontinued due to elevated levels of algae in the raw water, which when chlorinated create tastes and odours in the treated water.

b) Chemical Parameters

pH Value: The average monthly raw water pH generally is above 8.0 units and ranges from 7.5 to 8.7 units. A maximum daily pH value of 8.86 has been recorded. The greatest fluctuations occur during the algae growing season from May to September.

Alkalinity: Total alkalinity varies during the year from 78 to 97 mg/L as $CaCO_3$. The monthly average alkalinity value for the study period was 84.1 mg/L.

Hardness: The raw water hardness has a monthly average of 98.5 mg/L as $CaCO_3$. Little variation in this value has been observed, the range being from 92 to 106 mg/L. At this level of hardness the water may be classified as being moderately hard.

c) Microbiological Parameters

Bacteriological Water Quality

Lake Huron water at the treatment plant intake tested positive for total and fecal coliform organisms in all of the samples analyzed during the 3-year study period. Normally four raw water samples per week were analyzed for total coliform, fecal coliform and fecal streptococcus organisms; during 1987 the test frequency was reduced to about one sample per week. The multiple-tube fermentation (MPN) test procedure was utilized for the analyses. Treated water was analyzed by the presence-absence (P-A) coliform test procedure at a rate of about four samples per week for the entire study period.

The test results indicate that the raw water was polluted, at moderate levels, with contaminants of fecal origin and as such is hazardous for direct consumption without disinfection. A summary of the bacterial test results obtained for 1985 to 1987 is as follows:

Total Coliform: All tests for total coliform bacteria were positive with an MPN value of 6 to 100 counts per 100 mL. Only one test during the 3-year period of record had a density of 101 to 5000 counts per 100 mL.

Fecal Coliform: All tests for fecal coliform organisms, which are indicative of sewage pollution, were positive with an MPN value of 6 to 10 counts per 100 mL.

Fecal Streptococcus: Fecal streptococcus organisms were found at a density of one organism per mL of sample in all the tests analyzed. These organisms occur in the feces of humans and warm blooded animals and their presence in water points to contamination that is of sewage origin.

Nuisance Organisms (Algae)

Anywhere from one to five tests per month were carried out on the raw water during 1985 and 1986 for the presence of algae. Apparently no testing was done in 1987.

Monthly average algae counts ranged from 1 to 1999 A.S.U. per mL; whereas the monthly average for the two-year record was found to be 542 A.S.U. per mL. Blooms of diatom plankton occur in spring and fall when the raw water temperature is in the range of 10 to 15°C. The highest numbers typically occur during May and June. The diatoms are filter clogging, and when present in large numbers have a significant impact on the operation of the dual media filters.

A.3 SECURITY OF INTAKE

Lake Huron is a good raw water supply source and no plan exists for protection of the intake. Shipping lanes are far away from the intake and the risk of a major spill is low. In addition, there are no major industries upstream of the plant with potentially hazardous discharges to the lake.

TABLE A.1

LAKE HURON RAW WATER QUALITY CHARACTERISTICS

AT THE LONDON (LAKE HURON) WATER TREATMENT PLANT

	3-Year Summary, 1985 to 1987	
	Monthly Average Range	3-Year Average
Turbidity, FTU	2.0 - 21.7	9.0
pH, Units	7.54 - 8.73	8.01
Temperature, °C	3 - 22	11
Alkalinity as $CaCO_3$, mg/L	78.0 - 97.0	84.1
Hardness as $CaCO_3$, mg/L	92.0 - 106.0	98.5
Total Coliform (MPN)		
- 6-100 per 100 mL, No. of Samples	-	426
- 101-5000 per 100 mL, No. of Samples	-	1
Fecal Coliform (MPN)		
- 6-10 per 100 mL, No. of Samples	-	412
Algae, A.S.U. per mL	1 - 1999	542

SECTION B

FLOW MEASUREMENT

SECTION B - FLOW MEASUREMENT

B.1 METHOD OF MEASURING FLOWS

Flows are measured for:

- raw water - the low lift pump discharge to each of two Pretreatment Modules, North and South
- filter effluent - each individual filter
- filter backwash water - backwash water pump discharge, common header
- service water - total discharge of service water pumps and supply to Grand Bend
- plant output - high lift pump discharge in headers #1 and #2 to London pipeline
- sludge recirculation to clarifiers
- sludge wasting - feed to centrifuge #1 and #2.

The majority of primary flow elements consist of magnetic flow meters. Meters for filter effluent are of the short form Venturi tube-type, and the unit on the treated water supply to Grand Bend is a mechanical compound water meter.

Table B.1 lists information on existing flow meters and associated instrumentation. The sizes and capacities of the various flow meters are also given.

Magnetic flow meters are equipped with 0 - 10 mA DC transmitters, complete with indicators and totalizers, for signal transmission to indicating flow instruments mounted on local and remote control panels. Venturi flow meters are fitted with differential pressure transmitters with square root extractors to supply a linear flow signal to individual filter control consoles and to summators on the Main Control Panel.

Raw water is supplied by a single 1500 mm diameter pipe from the Low Lift Pumping Station. At the plant, flow is split in two with

TABLE B.1

FLOW METERING EQUIPMENT

Service/Location	Number	Type & Capacity Range	Instrumentation
1. Raw Water Flow . Chemical Building, Gallery No. 1	2	1-760 and 1 - 900 mm dia. magnetic flow meters on North & South Pretreatment Modules 0 - 182,000 m^3/d and 0 - 273,000 m^3/d capacity	local: 0 - 10 mA DC transmitter, indicator, 6-digit totalizer, one for each meter remote: 1) MCP - individual indicators, North & South flows; raw water flow summator, totalizer with indicator/-recorder 2) CCP - indicating control relay 3) SHCP - indicator, North & South
2. Filter Flow . Filter Building, Filter Pipe Gallery	12	460 mm dia. short form Venturi tube, one for each filter 0 - 34,100 m^3/d	local: 0 - 10 mA DC differential pressure (DP) transmitter, signal to MCP and individual FCC remote: 1) MCP - summators for flow from North & South filter banks; manual and auto operation filter flow summators with indicators; total filter flow summator with totalizer and indicator/recorder; total filter flow signal, Qm-manual or Qa-auto, to ACD;

TABLE B.1 - FLOW METERING EQUIPMENT (continued)

Service/Location	Number	Type & Capacity Range	Instrumentation
			2) FCC - input to filter rate controller, indicator 3) CCP - total filter flow indicating relay
3. Filter Backwash Water . Filter Building, Filter Pipe Gallery	1	600 mm dia. magnetic flow meter 0 - 136,400 m^3/d	local: 0 - 10 mA DC transmitter with indicator remote: 1) FCC - indicator each console 2) CFCD - indicating control relay 3) MCP - totalizer and indicator/recorder; input signal, Qw, to ACD
4. Service Water . High Lift Pumping Station, Pump Piping Floor	1	360 mm dia. magnetic flow meter 0 - 40,900 m^3/d	local: 0 - 10 mA DC transmitter with indicator remote: 1) MCP - totalizer and indicator/recorder; indicating control relays
	1	250 mm dia. mechanical compound water meter 0 - 144 L/s (supply to Grand Bend and Townships)	local: mechanical in-line totalizer on compound meter
5. Sludge Recirculation . Clarifier/ Sludge Handling Building, Pump Room	4	75 mm dia. magnetic flow meter 1.0 - 13 L/s	local: 4 - 20 mA DC transmitter, indicator and totalizer, one for each meter remote: 1) SHCP, North & South Panels - indicator/totalizer, each pump; control relays, interlocks and alarms

Service/Location	Number	Type & Capacity Range	Instrumentation
6. Sludge Wasting . Clarifier/ Sludge Handling Building, Pump Room	2	75 mm dia. magnetic flow meter 0 - 7 L/s	local: 4 - 20 mA DC transmitter indicator and totalizer, one for each meter remote: 1) SHCP, North & South Panels - indicator/totalizer; control relay and alarm
7. Plant Output (Pipeline Flow) . Meter Chamber on London Pipeline, East Side of H.L.P.S.	2	900 mm dia. magnetic flow meter 0 - 304,600 m^3/d	local: 0 - 10 mA DC transmitter, indicator/totalizer, each meter remote: 1) MCP - total pipeline flow summator, totalizer, indicator/recorder; input signal, Qp, to ACD

Legend

Local: At Instrument and Nearby Control Panel
Remote: At Central Control Station
MCP = Main Control Panel in Plant Control Room
CCP = Central Control Panel in Low Lift Pumping Station
FCC = Filter Control Console
CFCD = Central Filter Control Desk
ACD = Analogue Computing Device
SHCP = Sludge Handling Control Panel

individual branch headers (1060 mm dia. North Branch and 1370 mm dia. South Branch) supplying each half section of the pretreatment basins (rapid mix, flocculation, and sedimentation tanks). Flow is metered in the north branch header by a Kent 760 mm dia. magnetic flow meter and in the south branch header by a 900 mm dia. magnetic flow meter. Instrumentation for each meter includes a locally mounted indicator/-totalizer and flow transmitter. The main control panel includes individual indicators for north and south flows, a summator, and combined flow totalizer with indicator/recorder. The signal is also transmitted to the Central Control Panel in the Low Lift Pumping Station and the Sludge Handling Control Panel.

Recording of flow was done daily by reading the main control panel totalizer each day at midnight. However, more recently the accuracy of the raw water meters has become suspect, and the flows are calculated using daily flow meter readings for treated water, service water, and backwash water. The plant output flow meters are considered to be most accurate. They are periodically calibrated by pumping up the reservoir at the Ausable Booster Pumping Station.

Raw water represents the total daily flow taken into the plant, while treated water represents the total daily amount of water pumped into the distribution system.

Individual raw water flow signals (north and south) are used for quantitative pacing of chemical metering pumps for the primary coagulant (alum, ferric chloride or polyaluminum chloride), as well as the coagulant and/or filter aid, when used. The total summated raw water flow signal is used for quantitative pacing of the prechlorination dosage. Because the pacing signals are known to be slightly inaccurate, dosage settings are qualitatively adjusted, as necessary, in accordance with actual results achieved following treatment.

Filter effluent pipes are equipped with Venturi tube flow meters and rate control valves. The flow signals are transmitted to the filter process controllers which operate in conjunction with the filter rate controllers. Flow signals from the North Bank and South Bank of

filters are transmitted to respective summators on the Main Control Panel and to the total filter flow summators for manual and automatic operation, also located on the Main Control Panel. North and south bank filter flows are used for automatic pacing of the post-chlorinators. The total filter flow is indicated at the Main Control Panel and recorded. The signal also serves for control of the low lift pumps.

Recirculated settled sludge from each clarifier is measured by magnetic flow meter and transmitted to the North and South Sludge Handling Control Panels. Signals are used for monitoring purposes and for pump speed conditioning and pump shut-off on zero flow.

Excess sludge from the north and south bank clarifiers is pumped to centrifugation and is measured by magnetic flow meters. Flow is monitored locally by indicator/totalizer and transmitted to the Sludge Handling Control Panel for continuous flow indication and totalization.

The total in-plant water usage is measured and recorded, but no specific flow meter is available for monitoring the water used by the filter surface wash agitators.

The filter wash water is measured by magnetic flow meter in a common discharge header from the backwash pumps. The flow signal is used for monitoring purposes (filter control console, central filter console and Main Control Panel) and for automatic control of the wash water pumps. In the manual mode after the first duty pump has been initiated, the signal will automatically sequence the second and third duty pumps.

High lift pumps discharge via two 1060 mm dia. discharge headers (header #1 and #2) to the 1220 mm dia. London pipeline. Individual headers combine in the yard immediately downstream of the metering chamber. The London pipeline, with a length of about 48 km, terminates at the Arva Terminal Reservoir. Flow is measured by magnetic flow meters. There is one meter installed in each of the two discharge headers. Transmitters on each meter include local indicators and totalizers. The signal is transmitted to the total treated water flow

summator mounted on the Main Control Panel. The summator output is monitored by indicating recorder and totalizer, and serves as input signal, Qp, to the Analogue Computing Device.

Treated water supplied locally to Grand Bend by the service water pumps is measured and totalized by a mechanical compound water meter.

B.2 ACCURACY OF FLOW MEASUREMENTS

The initial flow meter accuracy has been assured by the use of magnetic flow meters on raw water, treated water, and service water pumpage, and Venturi tube primary flow elements for filter effluent flow. Both the magnetic flow meter primary element and the Venturi tube have specified accuracies of one-half of one per cent at mid-range of actual flow and one per cent at the extremeties of the flow range. In time, a loss of accuracy can occur with magnetic flow meter elements due to corrosion or accumulation of deposits on the internal electrodes. The impact of corrosion of the Venturi throat liner is of lesser importance in case of Venturi tube elements, although corrosion of the throat liner also will affect the accuracy of the meter.

Transmitting instruments and totalizers are subject to additional errors. Differential pressure sensor elements and flow signal transmitters have a specified accuracy of one-half of one per cent. The specified accuracy for totalizers is one per cent.

Using the above specifications, the maximum flow meter error of magnetic flow meters and Venturi tube flow meters should not exceed two and one-half per cent of actual flow. This error may increase by one-half of one percentage point for multiple meters with summated flow signals. The range in accuracy for multiple meters therefore can be in the order of plus or minus three per cent.

Secondary instruments, including the signal generating circuits and transmitters, are recalibrated periodically to ensure meter accuracy. To our knowledge, though, the primary flow elements have not been checked or overhauled since they were installed in 1967. These obser-

vations apply to all of the originally installed plant flow meters with the exception of the treated water plant output meters on the London pipeline. The pipeline to the Ausable Booster Pumping Station with its on-line storage reservoir has hydraulic characteristics suitable for flow testing of the meters by pumping up the reservoir. As such, a test is carried out periodically to check and recalibrate the flow meters, if necessary. The treated water flow meters are therefore used for monitoring and recording treated water and indirectly, through back-calculations using service water and filter wash water flow readings, raw water flows. From the plant records it is not evident when this procedure for recording raw water flows was implemented. Plant staff indicated that it may have occurred before 1985. Our analysis of the flow record summarized in Table 1.0 of Appendix C gives rise to the following observations:

- There is no inconsistency in average monthly flow records for either raw or treated water.

- The difference between raw and treated water flows when analysed statistically as a percentage of the treated water is as follows:

	1987	1986(1)	1985
. range, monthly average	0.79 - 2.68	3.42 - 8.16	2.83 - 7.58
. average	1.94	5.13	4.87

(1) 9 months record - January to September

- As a comparison to the above variances in raw and treated water flows, the amount of backwash water consumption was analysed as a percentage of treated water flow and the following results were obtained:

	1987	1986(1)	1985
. range, monthly average	1.80 - 2.68	3.39 - 8.16	2.87 - 7.63
. average	2.04	5.13	4.87

(1) 9 months record - January to September

The above analyses results show that on the basis of yearly averages, raw and treated water flows are in close agreement when taking into account the amount of backwash water consumption. However, consumption due to other in-plant uses are not included in the above analyses. In-plant consumption, referred to as service water, can amount to about 0.8 per cent of the total treated water flow.

In view of the close agreement in the average raw and treated water flows, it can be concluded with confidence that raw water flow meters have not been used for recording purposes during the past three years.

B.3 PER CAPITA WATER CONSUMPTION

The serviced population and per capita water consumption are summarized for 1985 to 1987 in Table 1.1. In 1987 the average day per capita consumption was 565 Lpcd whereas in 1986 and 1985 the unit water consumption rates were 514 and 511 Lpcd respectively. An increase in population was experienced from 291,000 in 1985 to 298,100 in 1987.

A breakdown of the 1987 population by municipality is as follows:

Municipality	1987 Serviced Population
Ailsa Craig	900
Grand Bend, average	1,300
seasonal	(900 to 4,000)
East Williams	452
Parkhill	1,375
Thedford	900
West Williams	1,000
Bosanquet Township, average	870
seasonal	(644 to 2,000)
Hay Township, approx.	360
McGillivray Township	1,824
Stephen Township	6,118
London Township - Denfield	120
- Ilderton	400
London City	282,500
Total, average	298,119
seasonal	(297,493 to 301,949)

We have examined 1986 industrial/institutional water consumption records for the City of London and found that about 14% of total annual consumption is drawn by major water users. This has a significant influence on the gross average day per capita consumption rate. During 1986, the following major water consumers exceeded an average daily consumption of 750 m^3/d.

Major Industrial/Institutional
Water Consumers - London

Consumer	1986 Average Day, m^3/d
Accuride Canada Inc.	787
CAE Webster Ltd.	1,857
ESAM Construction	1,373
Kellogg Salada Co.	1,973
Labatts Ontario	3,393
London Health Assoc.	881
London Hospital Linen	896
Silverwoods Dairies	1,130
St. Josephs Hospital	819
University Western Ontario	2,678
Victoria Hospital	1,917
Zymaize Inc.	3,521
Total Average Day Consumption, m^3/d	21,225

A listing of 1986 average day per capita water consumption for several cities in Ontario is presented below for comparison purposes to the London rate.

	Populated Served	1986 Average Day Per Capita Water Consumption, Lpcd
Hamilton	308,100	938
Kitchener	144,151	694
Mississsauga	324,000	597
Niagara Falls	68,843	777
Oakville	80,100	494
Ottawa	521,003	602
St. Catherines	149,520	762
Thunder Bay	110,920	642
Windsor	225,000	764
Average (for 9 cities), Lcpd		697

It will be noted that the London 1986 average day per capita consumption of 514 Lpcd was considerably lower than the rates for all but one of the nine cities that were analyzed.

SECTION C

PROCESS COMPONENTS

SECTION C - PROCESS COMPONENTS

C.1 GENERAL

The Lake Huron Water Supply System Water Treatment Plant was constructed from 1966 to 1967 with a design capacity of 336,400 m^3/d. The initial capacity provided was 168,200 m^3/d and following construction of the Ausable Booster pumping station mid-point on the London pipeline in 1977 the design capacity of 336,400 m^3/d was established. The plant components were designed with a 35 per cent overload capability for a maximum hydraulic flow rate of 454,600 m^3/d. Provisions were made for future expansion of the plant by the addition of one flocculation tank and one bank of six filters to the south of the constructed plant. The design capacity of the future expanded plant would be 454,600 m^3/d and the ultimate hydraulic flow rate 613,700 m^3/d.

The original plant was designed on the basis of the direct filtration process consisting of rapid mixing, two-stage flocculation in primary and secondary zones, and gravity, dual-media filtration at a maximum design filter rate of 11.7 m/h. Operations of the plant during the initial fifteen years of service proved that the plant was able to operate at the maximum design rate if the raw water was of suitable quality. Under conditions of high turbidity or high plankton densities in the raw water, the plant capacity was restricted to 136,000 m^3/d. To ensure reliable plant capacity at the design flow rate, sedimentation basins in the form of parallel plate clarifiers were installed during 1985 and 1986. Also, facilities were provided for handling and disposal of settled solids from the clarifiers consisting of solids thickeners integral with the clarifiers, sludge dewatering centrifuges, and space for truck loading of the dewatered sludge cake. Complementary facilities provided include chemical preparation and dosing systems, additional clear well storage and a maintenance shop. The Block Flow Diagram in Figure C.1 illustrates the currently available treatment facilities at the plant.

Treatment components are laid out into two modules, North and South, each containing pre-treatment facilities (rapid mix, flocculation and

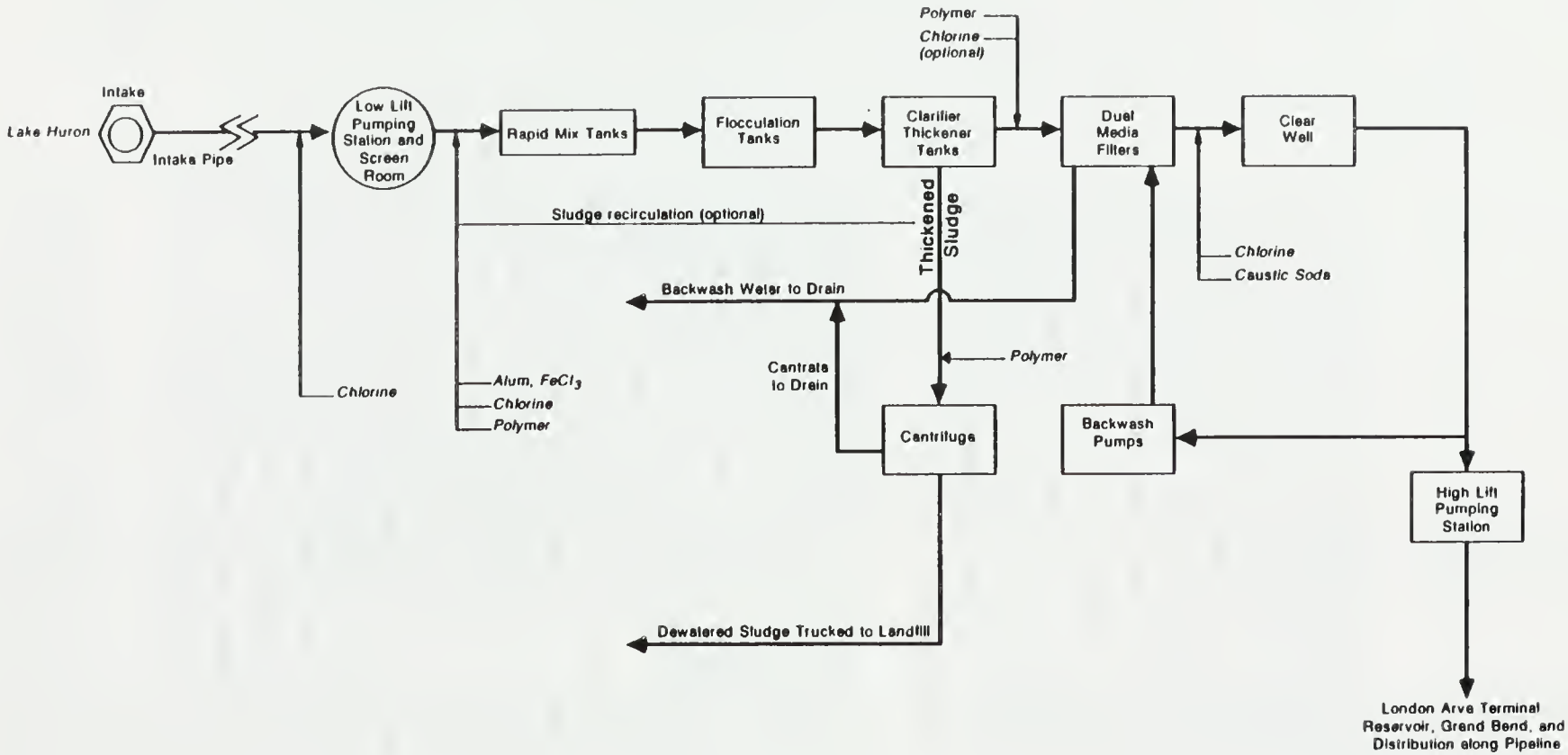

Figure C.1
LONDON (LAKE HURON) WATER TREATMENT PLANT
Block Flow Diagram

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clarification) and a bank of six filters. Raw water is drawn through a 1830 mm dia. concrete pressure pipe intake to a low lift pumping station located on top of the bank of the Lake Huron shoreline. The pumping station has a unique circular design and includes an inlet surge well, travelling raw water screens, a pump well, and vertical turbine pumps.

Water is pumped from the low lift pumping station through a 1500 mm dia. concrete pressure main to the treatment plant which is connected to the pumping station by the Low Lift Gallery. Inside the plant, in the Chemical Building, the raw water supply header divides into a 1060 mm dia. branch main supplying the North Pre-treatment Module and a 1370 mm dia. branch main supplying the South Pre-treatment Module. The latter branch header was oversized for the purpose of accommodating a future expansion. Each pre-treatment module consists of one rapid mix tank, one flocculation tank and two settling clarifier/thickeners.

Following pre-treatment, the water is filtered in twelve dual-media, gravity filters, six filters for each of the North and South Filter Banks. Filters are enclosed by the Filter Building which includes the filter operating gallery and pipe gallery below, located between the two banks of filters. Filtered water collects in a flume below the filters and discharges to the North and South Filtered Water Conduits and a two-celled Clear Well below the filters. Treated water from the Clear Well discharges to the High Lift Suction Conduit and the pump suction channels.

The High Lift Pumping Station includes the Administration and Maintenance Buildings. Pumping equipment consists of four high pressure pumps, three service water pumps, and three filter wash water pumps. High pressure pumps deliver water via 2 - 1060 mm dia. discharge headers and the 1220 mm dia. London pipeline to the Arva Terminal Reservoir situated about 6.4 km north of London. Service water pumps supply the in-plant water needs and deliver treated water via a 460 mm dia. main to the Village of Grand Bend.

Chemical treatment is provided in the form of:

- prechlorination of the raw water
- alum (and/or ferric chloride) coagulation
- polymer aids for coagulation and filtration
- polymer treatment for sludge dewatering
- postchlorination for disinfection
- caustic soda addition to the treated water for corrosion control and the control of post-filter precipitation of aluminum.

For possible future use bulk storage tanks for powdered activated carbon and activated sodium silicate where installed under the original contract.

The filter backwash waste water is discharged directly to the 900 mm dia. plant drain which connects to the 1070 mm dia. by about 500 m long outfall into Lake Huron.

C.2 DESIGN DATA

A summary of the design data and relevant plant information is presented in Table C.1. The Process Design Schematic in Figure C.2 illustrated the relationship of process components and provides a convenient overview of the sizing and capacities of these components.

a) Capacity

The plant design capacity is 336,400 m^3/d but the initial capacity was limited to 168,000 m^3/d by the capacity of the high lift pumps. Following the construction of the Ausable Booster Pumping Station midpoint on the London pipeline in 1977 and upgrading of the high lift pumps, the design capacity of 336,400 m^3/d was established. The plant has a 35 per cent overload capability which sets the maximum hydraulic flow capacity at 454,600 m^3/d.

Provisions were made for a future expansion of the plant by one-half its size for a maximum design capacity of 454,600 m^3/d and ultimate hydraulic flow rate of 613,700 m^3/d.

TABLE C.1

LONDON (LAKE HURON) WATER TREATMENT PLANT

DESIGN DATA AND PLANT INFORMATION

PLANT ADDRESS	
Plant Name	Lake Huron Water Supply System owned and operated by the Ontario Ministry of the Environment
Location	On shore of Lake Huron in Stephen Township, County of Huron
Plant Address	Ontario Ministry of the Environment P.O. Box 40 Grand Bend, Ontario NOM 1TO
Phone Number	(519) 238-8466
YEAR OF CONSTRUCTION/ COMMISSIONING	Plant was built in 1966 to 1967 and commissioned on June 27, 1967. In 1985 to October 1986 integral clarifier/thickeners and sludge handling facilities were installed.
WATER SOURCE	Lake Huron
PLANT CAPACITY	
Initial Capacity	168,200 m^3/d
Maximum 1987 Flow	357,090 m^3/d
Design Capacity	336,400 m^3/d
Maximum Hydraulic Flow	454,600 m^3/d

INTAKE

Crib	- 18 m dia. fabricated steel, octagonal-shaped intake crib enclosed by timber screen with 76 mm openings, 166.68 m top of crib elev.
	- 8.84 m submergence at low lake water level of 175.52 m
Intake Pipe	- 1830 mm dia. by 2530 m offshore, reinforced concrete pressure pipe, buried in the lake bottom
• Capacity	- 5,262 m^3/s at 175.52 m low W.L. in lake
• Surge Well	- 3.35 m to 5.89 m W x 13.72 m L x 12.50 m D, volume 828 m^3

LOW LIFT PUMPING STATION

Travelling Screens	- 2 dual-flow screens - 2.44 m W x 12.5 m H - installed, 1 future
Pumps	- 5 installed, 1 future (1988)
• Type	- vertical turbine driven by electric induction motors
• Capacity	- 3 @ 736.6 L/s @ 18.3 m TH; 167.9 kW motor
	- 2 @ 1,157.5 L/s @ 18.3 m TH; 261.1 kW motor
• Discharge Piping	- 3 @ 500 mm dia. increasing to 760 mm dia.
	- 2 @ 600 mm dia. increasing to 760 mm dia.
	- 1 - 1500 mm dia. common discharge to treatment plant

RAPID MIXING

No. of Units	- 2 baffled backmix reactors, 1 for each flocculation tank, with 2 chambers per tank in series
Chamber Dimensions	- 3.56 m W x 3.56 m L x 5.79 m D; 4.53 m SWD @ design flow
Volume	57.4 m^3 per chamber; 114.8 m^3 per tank
Detention Time	- 1.0 min. @ design flow
Rapid Mixers	- 4 vertical turbine mixers, 1 per chamber
• Impeller Type	- flat blade turbine impellers, 1500 mm dia.
• Motor Rating	- 11.2 kW
• G Value	- 350 s^{-1}
• Gt Product	- 21,000 design

FLOCCULATION

No. of Units	- 2 tanks, each divided equally into primary and secondary zones - each zone is divided into 2 chambers for series flow
Chamber Dimensions	- 5.03 m W x 17.81 m L x 8.19 m D; 7.26 m SWD @ design flow
Tank dimensions	- 20.12 m W x 17.81 m L x 8.19 m D
Inlet Arrangement	- 3.56 m W weir submerged 1.47 m @ design flow; 7.38 m^2 open area
Outlet Arrangement	- 3 ports, each 1.52 m W x 1.98 m H; 9.03 m^2 open area
Volume	- 2600 m^3 per tank, 1300 m^3 per zone
Capacity Range	- 31,800 - 168,200 m^3/d
Detention Time	- 22.3 min. design, 118 min. - 22.3 min. range
Flocculators	- 2 per tank, each including 3 shafts, 36 clusters, 6 paddles per cluster
• Motor Rating	- 11.2 kW each, 2:1 variable speed fluid drive
• G Value	- 23 to 65 s^{-1}
• Gt Product	- 30,800 to 87,000

SEDIMENTATION

No. of Tanks	- 4 tanks, rectangular, equipped with parallel plate settlers, solids thickening pickets and sludge collectors - the settling zone of each tank is divided into 2 halves by a central clarifier/thickener bridge and outlet trough assembly and inlet distribution channel below
Tank Dimensions	- 15.620 m W x 15.240 m L x 8.10 D, 6.75 m SWD @ design flow
Volume	- 440 m^3 settling zone; 390 m^3 sludge storage, 790 m^3 thickening zone
Detention Time	- 7.5 min. settling @ design flow, 28 min. overall @ design flow, per unit
Inlet Channel	- 4.57 m W x 1.90 m H overall
Outlet Trough	- rectangular, semi-circular bottom, R = 1.27 m , 3.30 m W x 2.45 m H overall
Plate Pack	- 75 plates spaced 50 mm apart, each 0.610 m W x 2.590 m L, 38 packs per tank, 55° to horizontal

SEDIMENTATION (continued)

Plate Pack (cont'd)	
• Projected Horiz. Surface Area	- 2,580 m^2 per tank
• Effective Overflow Rate	- 32.95 m/d or 1.37 m/h design
Sludge Thickener/Collector	- 15.24 m dia. sludge scraper mechanism with 2.4 m H pickets, 3.0 m overall height
• Motor Rating	- 1.5 kW
• Continuous Running Torque	- 7,468 kg·m
Sludge Recirculation Pump	- 4 horizontal, dry-pit open screw centrifugal pumps, 2 each for North and South Clarifiers, 100-1750 rpm
• Capacity	- 3.0 - 12.3 L/s, 18 m TH
• Motor	- 5.6 kW, AC/variable frequency controller
Sludge Waste Pumps	- 4 progressive cavity sludge pumps, 2 each for North and South Clarifiers, 100-350 rpm
• Capacity	- 0.7 - 3.5 L/s, 39.6 m TH
• Motor	- 3.7 kW, AC/variable frequency controller
Sludge Dewatering Centrifuge	- 2 solid bowl centrifuges, 1 future
• Capacity	- 255 L/min. feed rate, 612 kg/h total dry solids
• Motor	- 48 kW, 1800 rpm

FILTRATION

Type	- dual media, anthracite and sand, high rate gravity filters
Number	- 12 total, 6 on each side of a central pipe and operating gallery
Size	- 7.32 m W x 16.76 m L x 3.96 m D filter bays; each incl. 0.914 m W longitudinal wash water gullet and 6.10 m W x 16.76 m L filter; trough elev. is 2.29 m above floor

FILTRATION (continued)

Surface Area	- 102 m^2 per filter or 1224 m^2 total
Filter Rate	- 11.45 m/h @ design flow; 15.5 m/h max. hydraulic
Media	- 460 mm anthracite, E.S. = 0.90 mm, U.C. less than 1.71 - 300 mm sand, E.S. = 0.55 mm, U.C. 1.54 - 1.73 - 400 mm graded gravel, 5 layers 50 mm to 1.2 mm dia. - filters # 1 and 5 to 8 inclusive were re-built in 1977 and include the following media; 460 mm anthracite, E.S. = 1.6 mm, U.C. = 1.4 300 mm sand, E.S. = 0.8 mm, U.C. = 1.4 400 mm gravel, as before
Underdrains	- Miller, pre-cast concrete block, 300 mm W x 100 mm D each
Surface Wash	- 4.88 m dia. rotating jet, 3 per filter
Wash Water Rate	- 36 to 55 m/h max with 2 and 3 pumps respectively
Raw Water Conduit	- 3.05 m W x 2.54 m D x 42.21 m L, each North and South - 1.83 m W x 1.52 m D x 47.24 m L North-South cross-connect conduit
Filtered Water Conduit	- 2 conduits, North and South, 2.90 m W x 1.70 m D x 45.72 m L
Filter Valves and Piping	- 760 mm dia. motorized butterfly inlet valve - 1060 mm dia. motorized butterfly drain valve - 460 mm dia. filtered water effluent piping and Venturi flow meter - 460 mm dia. pneumatically operated filter rate control valve - 900 mm dia. wash water main with 760 mm dia. filter inlet and motorized 760 mm dia. wash water inlet valve - 200 mm dia. filter drain increasing to 300 mm dia. common filter drain header, 200 mm dia. manually operated gate valve - 200 mm dia. common surface wash header reducing to 100 mm dia. pipe to each filter, flow controlled by 100 mm dia. plug valve with pneumatic cylinder

CLEAR WELL

Number	- 2 clear wells, one for each bank of filters; each clear well is divided into 2 sections
Size	- 20.12 m W x 45.75 m L x 4.32 m D, 3.66 m SWD
Volume	- 3320 m^3 per well, 6640 m^3 total
Detention Time	- 28 min. @ design flow

HIGH LIFT PUMPING STATION

Treated Water Suction Channel	- 3.05 m W x 52.43 m L x 11.65 m D, 10.29 m max. SWD
Treated Water Pumps	- 4 horizontal, centrifugal, double suction; electric horizontal synchronous motor, space available for 2 future pumps
• Capacity	- 4 @ 1158 L/s @ 152.4 m TH, 2238 kW motor - 3474 L/s firm station capacity
Service Water Pumps	- 3 horizontal, centrifugal, double suction; 2 with electric induction motors and 1 with direct diesel engine drive
• Capacity	- 1 @ 49 L/s @ 73 m TH, 74.6 kW motor - 1 @ 66 L/s @ 73 m TH, 74.6 kW motor - 1 @ 80 L/s @ 73 m TH, 93.3 kW diesel engine
Wash Water Pumps	- 3 horizontal, centrifugal, double suction; electric induction motors; space available for 1 future pump
• Capacity	- 3 @ 530 L/s @ 15.2 m TH, 149.2 kW motors
Engine Generator Set	- 1 diesel engine generator, 100 kW, 575 V, 3 ph, 60 cy
Hydro-pneumatic Tank	- 2 units, 3.81 m dia. x 27 m L, 290 m^3 each, 2000 kPa

CHEMICAL PROCESSES

Original Plant

Chlorination	- gaseous chlorine applied in solution form

CHEMICAL PROCESSES (continued)

• Prechlorination	- applied through open channel diffuser 1) Surge Well of Low Lift P.S 2) North and South Flash Mixers 3) North and South Raw Water Conduits (when bypassing pretreatment)
• Postchlorination	- applied through open channel diffusers in North and South Filtered Water Conduits
• Storage	- space for 16 one-ton containers, single tier, plus 3 on scale - 1 - 3 one-ton container mechanical scale, dial cabinet with 500 mm dia. circular dial, transmitter and loss-of-weight recorder with alarm
• Chlorine Feeders	- 3 W & T Series A-711 chlorinators, 1 prechlorination and 2 postchlorination, 1 future - 908 kg/d capacity each, rotameter ratings are 454 kg/d prechlorinator and 227 kg/d postchlorinators
Coagulation	
• Liquid Alum	- bulk storage in 2 concrete tanks, 66,000 L each, 3.56 m square by 5.55 m high, 1 tank provided for future use
• Alum Transfer Pumps	- 2 - 1.89 L/s centrifugal pumps, 12.2 m TH, 1.49 kW motor
• Alum Feeders	- 2 - Rotodip, dipper wheel-type feeders with dilution tanks, 114 L/min capability, 0.53 to 5.3 L/min. range - applied at Flash Mixers
Powdered Activated Carbon	- 3 - 66,000 L lined and 2 - 66,000 L unlined concrete tanks were provided for future use; to be applied at Flash Mixers - tank dimensions are 3.56 m W x 3.56 m D x 5.55 m H
Sodium Silicate	- 2 - 66,000 L unlined concrete tanks were provided for future use; to be applied at Flash Mixers - tank dimensions are 3.56 m W x 3.56 m D x 5.55 m H

CHEMICAL PROCESSES (continued)

Liquid Ferric Chloride

• Application	- applied as a primary coagulant at the Flash Mixers
• Storage	- 2 - 27,000 L exterior, above-ground, insulated and heat traced fiberglass reinforced plastic tanks
• Metering Pumps	- 2 diaphragm pumps with variable speed SCR drives - 237 L/h @ 517 kPa
	- Note: 1) The use of $FeCl_3$ was discontinued on 4 Nov. 1986 2) Storage tanks will be used with future chlorine scrubbing system for storage of caustic soda.

Polymer System

• Application	- nonionic polymer solution applied as a filter aid to the Raw Water Conduits
• System Components	- 1 - 1,400 L plastic make-up and storage tank equipped with mixer - 2 diaphragm pumps with variable speed SCR drives

Plant Expansion

Coagulant Aid	- complete, automated system for use of dry or liquid cationic polymer - applied at flash mixers
• System Components	- volumetric feeder with hopper, 600 mm x 200 mm opening, 250 kg storage capacity, 1.0 - 1.6 kg/min. feeder capacity - hot air blower, piping and polymer wetting disperser
• Mix Tank	- 2.74 m dia. FRP (fibreglass reinforced plastic), 18,160 L capacity
• Solution Storage	- 3.56 m square, lined concrete tank (originally provided for activated carbon slurry) 66,000 L capacity
• Transfer Pumps	- 2 progresive cavity-type pumps, 18.0 L/s @ 21 m TH, 18.7 kW motor, 520 rpm

CHEMICAL PROCESSES (continued)

• Metering Pumps	- 3 variable speed, progressive cavity-type pumps (2 duty, 1 standby), 0.1 - 1.4 L/s @ 14 m TH, 2.2 kW motor, 0 - 520 rpm
• Accessories	- rotameters and positive displacement flow meters on polymer solution and dilution water - in-line, static mixer for polymer dilution after metering pump
Filter Aid	- complete, automated system for use of dry or liquid nonionic polymer - applied at Raw Water Conduit before Filters
• System Components	- volumetric feeder with hopper, 600 mm x 200 mm opening, 1.0 - 1.6 kg/min. feeder capacity - hot air blower, piping and polymer wetting disperser
• Mix Tank	- 1.52 m dia. FRP, 4,540 L capacity
• Solution Storage	- 2.74 m dia. FRP, 22,700 L capacity
• Transfer Pumps	- 2 progressive cavity-type pumps, 1.0 L/s @ 10 m TH, 1.5 kW motor, 360 rpm
• Metering Pumps	- 3 variable speed, progressive cavity-type pumps (2 duty, 1 standby), 0.1 - 0.3 L/s @ 14 m TH, 1.1 kW motor, 0 - 400 rpm
• Accessories	- rotameters and positive displacement flow meters on polymer solution and dilution water - in-line, static mixer for polymer dilution after metering pump
Dewatering Aid	- complete, automated system for use of dry or liquid anionic polymer, applied to feed stream of sludge dewatering centrifuge
• System components	- volumetric feeder with hopper, 600 mm x 200 mm opening, 1.0 - 1.6 kg/min. feeder capacity - hot air blower, piping and polymer wetting disperser
• Mix Tank	- 1.98 m dia. FRP, 6,810 L capacity
• Solution Storage	- 2.44 m dia. FRP, 13,620 L capacity

CHEMICAL PROCESSES (continued)

• Transfer Pumps	- 2 progressive cavity-type pumps, 6.4 L/s @ 10 m TH, 7.5 kW motor, 520 rpm
• Metering Pumps	- 3 variable speed, progressive cavity type pumps (2 duty, 1 standby), 0.1 - 0.6 L/s @ 14 m TH, 1.1 kW motor, 0-600 rpm
• Accessories	- rotameters and positive displacement flow meters on polymer solution and dilution water - in-line, static mixer for polymer dilution after metering pump
pH Adjustment	- application of liquid caustic soda at the inlet to the Clear Wells in the Filtered Water Conduits and the Flash Mixers
• Solution Storage	- 3.56 m square lined concrete tank (originally provided for activated carbon slurry), 66,000 L capacity
• Metering Pumps	- 3 cam drive, hydraulic diaphragm, double head pumps (2 duty, 1 standby), 2.12 L/min. @ 28 m TH, 125 watt DC/SCR variable speed drive, 0 - 120 spm (strokes per min.)
• Accessories	- dilution water to bulk storage tank with 40 mm dia. positive displacement flow meter
On-Line Monitors	
• Turbidity	- on-line, Surface Scatter Turbidimeters, Nephelometric Standard: . 1 - unit for monitoring raw and coagulated water, North and South Modules . 1 - unit for monitoring settled water - North and South Modules . 1 - unit for monitoring filter effluent, each filter, with auto sample switching every 6 minutes . 1 - unit for monitoring the final plant effluent - instrumentation includes local indication and signal transmission to indicating recorders on Main Control Panel (MCP) and to Allan Bradley PC (installed 1988) and data line printer

CHEMICAL PROCESSES (continued)

- Temperature - raw water in surge well, 1-resistance thermometer, -1°C to 27°C range, transmitter and indicating recorder on MCP
- Streaming Current Monitor - 2 units available for predicting the optimum coagulant dosage
  . 1 - Chemtrac Monitor on South Module
  . 1 - Milton Roy Monitor on North Module
- Chlorine Residual - 1 - amperometric analyzer unit, 0 to 2 mg/L range, high/low chlorine residual alarm, local indication and signal tranmission to indicating recorder and alarm annunciation on MCP

As indicated in the previous section, however, the design capacity of 336,400 m^3/d with the direct filtration process could only be achieved with good raw water quality. During periods of high raw water turbidity or high plankton densities, plant capacity was restricted to 136,000 m^3/d. Consequently, parallel-plate clarifiers were installed in 1985 to 1986 which ensured continuous production at the design capacity of the plant under all raw water quality conditions.

b) Capacity Limitations

Prior to October 1986, the plant operated in the direct filtration process. Up to this time plant capacity and/or treatment effectiveness was limited at certain times of the year by the following conditions:

- A relatively low level of colloidal turbidity may be encountered (less than 10 FTU) which is difficult to destabilize.

- Conditions of high raw water turbidity or high plankton counts would limit filter runs to the extent that while filtered water quality was satisfactory, plant capacity was significantly reduced. High turbidities in excess of 100 FTU can be encountered during spring runoff and during major storm events which tend to stir up the lake bottom. Diatom plankton blooms occur in May and June when the water temperature rises and is in the range of 10 to 15°C, and again in the fall when temperatures come back down and pass through this range. Plankton blooms are perhaps the more serious conditions because they can persist for many days at a time. At such times, plant capacity was limited to 136,000 m^3/d.

With the addition of settling clarifier/thickeners to the pretreatment process, the design capacity of 336,400 m^3/d is no longer limited by seasonal adverse raw water quality.

C.3 PROCESS COMPONENTS INVENTORY

a) Intake

The intake consists of an 1830 mm dia. reinforced concrete pressure pipe constructed in a trench below the lake bed.

The crib is octagonal in shape, 18 m in dia., is fabricated of steel, and is enclosed by a wooden screen with 75 mm wide openings. It is located 2530 m off-shore in about 15 m of water. At minimum lake level of 175.52 m, the crib is submerged by 8.84 m.

The intake has a capacity of 5,262 L/s at 175.52 m minimum lake water level. The volume of the intake is about 6,700 m^3.

A surge well on the intake is included in the Low Lift Pumping Station. The displacement volume of the surge well is 830 m^3.

No problems have been experienced with the operation of the intake. It can be backflushed, if necessary, by a 760 mm dia. branch header from the pump discharge.

b) Raw Water Screens

Two dual-flow raw water screens are installed each measuring 2.44 m wide by 12.5 m high. One screen was originally provided and the second one was installed in 1985. Space is available for the installation of one future screen. Screens are of the continuous belt type and have a galvanized wire mesh with 13 mm dia. clear openings. Other parts of the screen are made of rigid steel.

Screen operation is manual by push-button controls. Automatic controls are available based on an air bubbler level sensor upstream and downstream of the screen. In the automatic mode screens will start operation based on 50 mm differential head in the screen channel and sustain operation until shut-down by a pre-set timer. Screens will lock out at 100 mm water column differential and an alarm will sound at the Central Control Panel (Low Lift Pumping Station) and the Main Control Panel.

Screens are operated for 10 to 15 minutes per week mainly for exercising of the mechanical equipment. Few, if any, coarse solids ever accumulate on the screens. They function primarily to keep out occasional fish and frazil ice that is drawn in during the spring when the ice melts. When the screens are running they are cleaned automatically by a water spray which discharges to the plant drain.

c) Low Lift Pumping Station

The Low Lift Pumping Station is designed for vertical turbine, centrifugal pumps. Two pump wells are provided with three pump bays in each. Five pumps are installed and the sixth pump is scheduled for installation in 1988.

A description of the available pumps and their capacities is given in Table C.2. It will be noticed that the installed rated pumping capacity is 390,900 m^3/d and with the largest unit out of operation, the firm station capacity is 290,900 m^3/d. Pumps discharge into 760 mm dia. branch headers of a Y-shaped manifold which is connected to the 1500 mm dia. raw water main leading to the treatment plant. In case of power failure all pumps shut down. Standby power generation capacity is only available for maintaining electrical controls and essential services such as sump pumps and emergency lighting.

The operation of the low lift pumps can be either automatic or manual as selected by the system control switch on the Central Control Panel.

In the manual mode low lift pumps may be operated from the Central Control Panel or the Main Control Panel and are selected based on level in the Raw Water Conduit (following the plant expansion, this conduit is more appropriately referred to as the Pre-filtered Water Conduit) and the filter rate. Shut down also would be manual following a high level alarm.

The normal procedure is to control pumps automatically. In this mode, pumps are controlled by both filter rate and water level in the Raw Water Conduit. The level control system functions to maintain the water level in the conduit. The control range between high and low water levels is set at 460 mm. The filter rate signal is used to determine the number of pumps in service. At low water level in the conduit and increasing filter rate, an additional duty pump will start whereas at high water level and decreasing filter rate an additional duty pump will stop to meet the change in demand.

TABLE C.2

RAW WATER PUMPS

Pump No.	Rated Capacity Flow L/s	Rated Capacity Head m	Type	Motor Rating kW	Manufacturer Pump/Motor
1 & 5	1,175.5	18.3	vertical centrifugal	261.1	#1 - Johnston, #5 - Peerless US Motors
2*	future				
3, 4 & 6	736.6	18.3	vertical centrifugal	167.9	Worthington Tamper Motors

* Scheduled for installation in 1988
Gould pump with US Motors - 298.4 kW motor.

Notes:

Installed Capacity: 390,900 m^3/d
Firm Capacity: 290,900 m^3/d

When a pump is switched to a maintenance socket all automatic controls are isolated and manual control is available only from the local control panel at the pump unit.

d) Rapid Mixing

Pre-treatment units are arranged in two parallel modules, the North Module and South Module.

Before October 1986, the plant was a direct filtration plant where the pre-treatment process consisted of rapid mixing for dispersion of chemical coagulant (alum or ferric chloride), followed by flocculation. Following the construction and commissioning of clarifier settling tanks in October 1986, the treatment process has been changed to what is commonly referred to as "conventional treatment" although the process units in themselves are not conventional and represent the latest state-of-the art in settling technology. Therefore, pre-treatment units in the current plant consist of rapid mixing, flocculation and sedimentation tanks.

The rapid mix tanks, or flash mix tanks as they are sometimes called, consist of two baffled backmix reactors, one for each flocculation tank, with two chambers per tank in series. Each chamber measures 3.56 m by 3.56 m by 5.79 m high. For a side water depth (SWD) of 4.53 m at design flow, the resulting volume per chamber is 57.4 m^3 or 114.8 m^3 per tank and the detention time is 1.0 minute.

One vertical, flat-blade, turbine mixer is installed in each chamber. The motor has a rated capacity of 11.2 kW and operates at 1750 rpm. The mixer shaft speed is 37 rpm.

Process design parameters vary with plant flow as is illustrated in Table C.3 following. The minimum flow rate shown represents the average minimum flow rate for February 1987; the maximum was achieved in July 1987. At the design flow rate the mean velocity gradient, G, is 350 m/s.m (s^{-1}) and the Gt product is 21,000. Coagulant solution is applied through open-ended type pipes discharging at the height of the impellers.

TABLE C.3

RAPID MIXING PROCESS DESIGN

Plant Flow, m^3/d	Detention Time, s	G Value, s^{-1}	Gt Product
79,770 - minimum	124 [1]	350	43,400
336,400 - design	60	350	21,000
357,090 - maximum	56	350	19,600

[1] 1 tank in service

Flow from the second chamber of the rapid mix tank flows into the flocculation tank. The flow discharges over a broad-crested weir, 3.56 m wide - the width of the chamber, near the top of the tank. At the design flow rate the depth of submergence is 1.47 m.

e) Flocculation

Each Pretreatment Module contains one flocculation tank which is divided into Primary and Secondary Treatment Zones permitting the use of either constant or two stage tapered mechanical flocculation. Each zone is further divided into two chambers for series flow.

All cells are equal in size and measure 5.03 m W by x 17.81 m L x 8.18 m D. The side water depth at the design flow rate is 7.26 m and the resulting volume per cell is 650 m^3 or 1300 m^3 per mixing zone. The overall tank volume at the design flow is 2600 m^3.

Each flocculation zone is equipped with a "walking beam" paddle-type flocculator which contains three shafts with two sets of paddle arms per shaft. There are a total of thirty-six paddle clusters per flocculator each containing six paddles. The mixing energy can be varied by changing the stroke speed of the paddle arms. Motor ratings and process design parameters are presented in Table C.4. It will be noted that flocculators achieve average mean velocity gradients of 23 to 65 s^{-1} in each zone. The detention time varies with flow and ranges from 47.0 minutes to 21.0 minutes for minimum and maximum flows. At the design flow rate the detention time is 22.3 minutes and the Gt product can vary from 30,800 to 87,000.

The flocculation tank inlet velocities are:

Plant Flow, m^3/d	Inlet Velocity, m/s
79,770 - minimum	0.18[1]
336,400 - design	0.37
357,000 - maximum	0.39

[1] 1 tank in service

TABLE C.4

FLOCCULATION PROCESS DESIGN

A. FLOCCULATOR SPECIFICATION

Unit	Flocculator	Motor Rating, kW	Stroke Length & Speed m/spm	G Value s^{-1}
Tank 1 & 2				
• Primary Zone	walking beam, 3 shafts with 12 clusters per shaft, 6 paddels per cluster, common drive	11.2 2:1 variable speed drive	1.71/3.32	23 to 65
• Secondary Zone	walking beam, 3 shafts with 12 clusters per shaft, 6 paddles per cluster, common drive	11.2 2:1 variable speed drive	1.71/3.32	23 to 65

B. PROCESS DESIGN

Plant Flow m^3/d	Detention Time min.	Gt Product
79,770 - minimum	47.0 [1]	64,900 to 183,300
336,400 - design	22.3	30,800 to 87,000
357,090 - maximum	21.0	29,000 to 81,900

[1] 1 tank in service

Flocculated water, in the direct filtration mode, discharges through a 1.83 m W x 1.52 m H sluice gate to the Raw Water Conduit (before the filters). With sedimentation, the flocculated water discharges to the Pre-settled Water Conduit via three outlet ports each measuring 1.52 m W x 1.98 m H.

f) Sedimentation

Sedimentation tanks, two for each Pretreatment Module, were installed during 1985 to 1986 and consist of Lamella parallel plate clarifiers with integral sludge thickeners. Each clarifier measures 15.62 m W x 15.24 m L x 8.10 m D and has an operating side water depth of 6.75 m at the design flow rate. The total tank volume is 1620 m^3 and consists of a 440 m^3 settling zone, a 390 m^3 sludge storage zone below the plate packs, and a 790 m^3 sludge thickening zone. The latter zone includes solids thickening pickets and a mechanical sludge collector.

Clarifier plate packs are loaded from a central feed conduit located directly below the clarified water outlet channel. Clarifier specifications and process design parameters are presented in Table C.5. It will be noted that the projected horizontal surface area of the parallel plates, which are set at 55° to the horizontal, is 2,580 m^2 per clarifier. This results in an equivalent surface loading or overflow rate of 1.37 m/h at the design flow of 340,000 m^3/d. The overall detention time in the clarifier/thickener at the design flow is 27.5 minutes while in the settling zone above it is 7.5 minutes. Process parameters for minimum and maximum 1987 plant flows are given in Table C.5.

Plate packs include collector troughs at the top, one for each plate pack, which discharge into the outlet channel from where the clarified water is conveyed to the filters. The flow distribution to the plates is laminar throughout. This is achieved by three outlet orifices between plates located in the floor of the collector troughs. A description of the dimensions of the plate packs, inlet conduit and outlet channel are given in Table C.1.

TABLE C.5

SEDIMENTATION PROCESS DESIGN

LAMELLA SEPARATOR CLARIFIER/THICKENER

A. SPECIFICATIONS

Number of Units	4
Design Flow, m^3/d	
• Total	340,000
• Range, Total	136,000 to 340,000
• Per Unit	85,000
Hydraulic Capacity, m^3/d	
• Per 2 Units	255,000
Dimensions,	
• Unit Tank Dimensions, m	15.24 x 15.62 x 8.10
• Side Water Depth, m	6.75
• Plate Pack Dimensions, m	0.61 x 4.65 x 2.59
• Projected Horizontal Surface Area of Plates, m^2	2,580
• Volume per Unit, m^3	
- settling zone	440
- sludge storage/thickening zone	1,180

B. PROCESS DESIGN

		1987 Plant Flows	
	Design Flow 340,000 m^3/d	79,700 m/d (minimum)	357,090 m^3/d (maximum)
Surface Loading, m/h	1.37	0.64 [1]	1.44
Overall Detention Time, min.	27.5	58.5 [1]	26.1
Settling Zone Detention Time, min.	7.5	15.9 [1]	7.1

[1] 2 Units in service

Provisions have been made for recirculating settled and thickened sludge at controlled rates to the flocculation tanks. Recycling of solids to the rapid mix tanks, as much as to maintain 1000 mg/L suspended solids in the process flow, will enhance flocculation by providing a seed upon which the floc can grow and thus produce a denser floc with better settling characteristics.

There are four sludge recirculation pumps, two each for north and south clarifiers. Pumps are of the open screw centrifugal type rated at 3.0 to 12.3 L/s at 18 m total head. Variable speed AC frequency control motors are rated at 5.6 kW (Table C.6).

The rate of solids recycle is paced by either the north or south raw water flow signal via a process controller. The flow set point of the process controller is conditioned by a discharge flow signal from the sludge recycle magnetic flow meter and in future, the set point will be automatically adjusted based on sludge density.

Sludge removal from the clarifiers is automatic by a rotating sludge scraper mechanism which moves thickened solids to a central hopper from where it is withdrawn, as necessary, by sludge waste pumps.

g) Sludge Treatment and Disposal

Facilities for the treatment and disposal of solids generated from the sedimentation process were provided with the plant expansion in 1985 to 1986.

As already mentioned previously, facilities consist of picket solids thickeners which are included in the same tankage as the parallel plate settlers, and sludge dewatering centrifuges. Excess sludge is pumped to the centrifuge, conditioned with an anionic polymer solution, and dewatered. The resultant "wet" sludge cake, with a consistency of 20 to 40 per cent dry solids, is disposed of by truck to a nearby sanitary landfill. The centrate overflows to the plant drain and is returned to the lake.

TABLE C.6

SLUDGE RECIRCULATION AND WASTE PUMPS

Pump No.	Rated Capacity Flow L/s	Rated Capacity Head m	Type	Motor Rating kW	Manufacturer Pump Motor
Sludge Recirculation					
RP-1, 2, 3 & 4	3.0-12.3	18	horizontal, open screw centrifugal	5.6 variable speed	Wemco-Hidrostal Sterling Electric
Sludge Wasting					
WP-1, 2, 3 & 4	0.7-3.5	39.6	progressive cavity	3.7 variable speed	Moyno-Robbins Myers Sterling Electric

Sludge Waste Pumps

All pumping equipment, sludge recirculation and sludge waste pumps, is located on the lower floor of the clarifier/thickener building in the Pump Room. There are four progressive cavity sludge pumps, two each for north and south clarifiers. Pumps have a rated capacity of 0.7 to 3.5 L/s at a total head of 39.6 m. Pump drives are variable speed, AC frequency controlled, and are rated at 3.7 kW (Table C.7).

Sludge from respective clarifiers can be pumped to one or two (initially or three in future) centrifuges for dewatering and disposal. The feed stream is metered by magnetic flow meter and can be manually controlled by adjusting the speed of the pump either locally or remotely at the centrifuge. Pump speed indication is provided at either location.

Sludge Dewatering Centrifuge

Centrifuges for sludge dewatering consist of the solid bowl, scroll type units. Two centrifuges have been provided complete with separately floor mounted control panels; space is available for the addition of one future unit.

Centrifuges are rated for a maximum sludge feed rate of 255 L/min. or 612 kg/h total dry solids and are driven by 48 kW, 1800 rpm motors. The units are operated manually from their respective control panels.

h) Filters

The plant has twelve dual-media, gravity filters. They are arranged in two banks of six filters, North and South, alongside a central pipe gallery and filter operating gallery above. Filters operate on the principle of constant rate filtration. The design filtration rate is 11.7 m/h and the maximum hydraulic capacity is 15.5 m/h.

Filters are rectangular in shape and include one wash water gullet along one longitudinal side of each filter. Filter bays measure 7.32 m

wide by 16.76 m long by 3.96 m deep. The wash water gullet is 0.914 m wide and the filter is 6.10 m wide. The wash water through weir elevation is 2.29 m above the floor of the filter bay. Each filter has a surface area of 102 m^2 and the total area for twelve filters is 1224 m^2.

The 300 mm wide by 100 mm deep Miller block underdrains are covered with five layers of graded gravel ranging in size from 50 mm to 1.2 mm with a total depth of 400 mm. The filter media consists of a layer of sand and anthracite with the following characteristics.

Filter	Media	Depth, mm	E.S., mm	U.C.
2, 3, 4 and	anthracite	460	0.90	<1.71
9,10,11 & 12(1)	sand	300	0.55	1.54 - 1.73
1, 5, 6	anthracite	460	1.60	1.4
7 & 8(2)	sand	300	0.80	1.4

(1) original media installed in 1967
(2) new media installed in 1977

Filtered water collects in a dual-chamber filter effluent flume below the floor of the filter. It then discharges via the effluent piping to one of two Filtered Water Conduits, Conduit No. 1 and No. 2 serving the north and south filter banks respectively. Specifically, filter valves and piping include:

- 760 mm dia. motorized butterfly inlet valve
- 1060 mm dia. motorized butterfly drain valve
- 460 mm dia. filtered water effluent piping and Venturi flow meter
- 460 mm dia. pneumatic cylinder operated filter rate control valve
- 900 mm dia. backwash water pipe with 760 mm dia. filter inlet pipe and 760 mm dia. motorized butterfly valve
- 200 mm dia. filter drain pipe with manually operated gate valve
- 300 mm dia. common filter drain header.

Filters are equipped with three 4.88 m dia. rotating jet surface agitators. Backwash pumps are available for a maximum wash water rise rate of 55 m/h with three pumps.

Wash Water System

Backwashing is accomplished with a direct pumped water backwash system consisting of three horizontal, centrifugal, double suction pumps, driven by electric induction motors. Pumps are of Worthington manufacture and motors by Tamper Motors. Pumps have a capacity of 530 L/s at a total head of 15.2 m. The motor rating is 149.2 kW. Provisions on the pump floor have been made for the installation of one additional future pump. Table C.7 summarizes wash water pumping equipment available at the plant.

Filter backwash water is discharged to the 900 mm dia. plant drain which conveys flows to the 1060 mm dia. Lake Huron outfall.

Filter Instrumentation

Filter instrumentation equipment includes the following:

- individual Filter Control Consoles
- filter control switch, Manual-Off-Auto, and indication
- indicating process controller for filter rate control
- filter rate control servo-mechanism
- filter effluent flow measurement with transmitter to filter console, Central Control Desk, and Main Control Panel
- filter head loss measurement with signal transmission to Filter Control Console
- clear well level measurement for control of filter rate in the automatic mode
- rate of change of filtration rate measurement for input to Analogue Computing Device on Main Control Panel and secondary control of low lift pumps
- various control switches and pushbuttons with status indication for motorized valves, filter rate controllers, and wash water pumps

TABLE C.7

TREATED WATER PUMPS

Pump No.	Rated Capacity Flow L/s	Rated Capacity Head m	Type	Motor Rating kW	Manufacturer Pump Motor
High Lift					
1 & 6	Future				
2, 3, 4 & 5	1,158	152.4	centrifugal	2238	Allis-Chalmers Canadian General Electric
Service Water					
11	49	73	centrifugal	74.6	Worthington Brooks
12 & 15	Future				
13	66	73	centrifugal	74.6	Worthington Brooks
14	80	73	centrifugal	93.3	Worthington Cummins Diesel Engine

Notes:

Installed Capacity:
High Lift Pumps: 400,200 m^3/d
Service Water Pumps: 16,800 m^3/d

Firm Capacity:
High Lift Pumps: 300,200 m^3/d
Service Water Pumps: 9,900 m^3/d

- filter backwash program resident in individual Filter Control Consoles which is manually initiated when in the auto mode based on time "in service" or high head loss
- filter wash program control switch, Manual-Off-Auto, and push-button
- wash water flow measurement with indicating transmitter for signal transmission to the Filter Console, Central Control Desk, and Main Control Panel.

i) Clear Well

Flow from the filters discharges into two pressurized Filtered Water Conduits, Conduit No. 1 and No. 2 serving the North and South filters. Conduits measure 2.90 m wide by 1.70 m deep by 45.72 m long.

The conduits convey filtered water to the Clear Wells which are located below the filters. Each Clear Well has dimensions of 20.12 m wide by 45.75 m long by 4.32 m deep and is divided by a longitudinal baffle wall to ensure plug flow and good mixing of post-treatment chemicals that are added to the flow at the inlet. The maximum side water depth is 3.66 m which results in a maximum storage volume of 3,320 m^3 per well or 6,640 m^3 total. The water level is variable and depends upon the imbalance in low and high lift pumping rates and the operation of the wash water pumps. At maximum water level the detention time at the design flow rate is 28 minutes.

j) High Lift Pumping

The High Lift Pumping Station has space for six high head treated water pumps, five service water pumps and four wash water pumps. The existing installation includes four high head, treated water pumps, three service water pumps, and three wash water pumps. All pumps are of the horizontal, double suction, centrifugal type with bottom suction and side discharge ports. High lift pumps are driven by electric, horizontal synchronous motors. Two of the service water pumps have electric induction motors and one pump has a direct diesel engine drive. Suction is taken from the Treated Water Suction Channel which measures

3.05 m wide by 52.43 m long and 11.65 m deep; the maximum side water depth is 10.29 m. Pump capacities and motor ratings for treated water pumps are tabulated in Table C.8.

The installed station capacity is as follows:

- high lift pumps: 400,200 m^3/d
- service water pumps: 16,800 m^3/d

With the largest pump out of service, the firm pumping capacity for each system is:

- high lift pumps: 300,200 m^3/d
- service water pumps: 9,900 m^3/d

No standby power is available to run electric motor driven pumps during an emergency power outage.

High lift pump discharge valves are motorized and are normally interlocked with their related pump unit for all modes of pump control so that the valve functions as combined stop-check-throttle service. Valves may also be operated manually for throttling purposes from the Main Control Panel. Pumps discharge through two 1060 mm dia. branch headers to the 1220 mm dia. London pipeline. Plant output is metered in each of the two branch headers by 900 mm dia. magnetic flow meters.

Control of the high lift pumps and their respective discharge valves is remote manual from the Main Control Panel. Pumps are selected to maintain within a set range the level in the Arva Terminal Reservoir.

An automatic control mode is also available and can be selected by the system control switch on the Main Control Panel. However, in the interest of minimizing peak power consumption, experience has shown that the pumps at the High Lift Pumping Station as well as at the Ausable Booster Pumping Station (midway on the pipeline to the Arva Terminal Reservoir) can be operated manually. Pumps and valves at the booster station are controlled manually by electronic programmable controller from the Main Control Room via a microwave system.

TABLE C.8

TREATED WATER PUMPS

Pump No.	Rated Capacity Flow L/s	Rated Capacity Head m	Type	Motor Rating kW	Manufacturer Pump Motor
High Lift					
1 & 6	Future				
2, 3, 4 & 5	1,158	152.4	centrifugal	2238	Allis-Chalmers Canadian General Electric
Service Water					
11	49	73	centrifugal	74.6	Worthington Brooks
12 & 15	Future				
13	66	73	centrifugal	74.6	Worthington Brooks
14	80	73	centrifugal	93.3	Worthington Cummins Diesel Engine

Notes:

Installed Capacity:
High Lift Pumps: 400,200 m^3/d
Service Water Pumps: 16,800 m^3/d

Firm Capacity:
High Lift Pumps: 300,200 m^3/d
Service Water Pumps: 9,900 m^3/d

Information on flows, water levels and chlorine residuals at the Arva Terminal Reservoir is transmitted by microwave signal (via a repeater at the booster station site) to the Main Control Room at the treatment plant. The radio system also provides for voice communication between Arva, the booster and the treatment plant, and provides for remote manual control of the inlet and outlet valves at the Arva Terminal Reservoir.

Service water pumps are manually controlled from the Main Control Panel. An automatic mode is available whereby the base duty pump is operated manually and other pumps are sequenced according to the flow demand.

Service water pumps supply the in-plant water needs and deliver treated water to Grand Bend through an 460 mm dia. transmission main. The total service water flow is measured by a 350 mm dia. magnetic flow meter and the portion delivered to distribution is measured by a 250 mm dia. mechanical compound type water meter.

Surge relief facilities are available on the London pipeline in the form of two hydro-pneumatic tanks. The tanks measure 3.81 m in diameter, are 27 m long, and have a combined storage volume of 580 m^3. The air pressure in the tanks is maintained automatically at 2000 kPa by on-line air compressors which are controlled by the level of the water in the surge tanks. A direct differential pressure level sensing transmitter with local indicator provides a level signal to the indicating recorder on the Main Control Panel.

k) Standby Power

Standby power is available from one Cummins diesel engine generator set rated at 100 kW, 125 kVA, 0.8 p.f., 575 V, 3 phase, 60 cycle. Additional capacity will be available from a second unit to be installed later in 1988.

During a power outage, the generator will start-up automatically and maintain instrumentation and essential services such as sump pumps and emergency lighting facilities.

C.4 CHEMICAL SYSTEMS

C.4.1 LIQUID CHEMICAL FEED EQUIPMENT

a) Liquid Alum

The following equipment is available for storing and feeding liquid alum as a primary coagulant to the flash mixers:

- 2 - 66.0 m^3 bulk storage tanks, concrete, approx. dimensions 3.56 m square by 5.55 m high - 1 additional tank of same capacity is available for future use
- 2 - 1.89 L/s centrifugal transfer pumps, 12.2 m TH, 1.49 kW motor, 1 pump for each tank
- 2 - Rotodip, dipper wheel-type feeders, 114 L/min. capability, 1.5 L/min. max. rate, 0.53 to 5.3 L/min. range; service water added in dilution tank downstream of feeder
- liquid alum stock solution diluted by 50% to 24.1% alum.

Alum feeders are equipped with automatic proportional-to-flow controls; dosage adjustment is manual. The raw water flow signal from the respective plant module is used for pacing of alum dosage. A flow transmitter on suction side of feeder will transmit a low alum flow alarm signal to annunciator on Main Control Panel.

b) Liquid Ferric Chloride

Liquid ferric chloride storage and feed equipment was added to the plant at a later date. The chemical is a primary coagulant which during 1985 and 1986 was still used either instead of alum or together with alum in the coagulation process. Following the plant expansion (commissioned in October 1986), ferric chloride was no longer used. In future, the existing bulk storage tanks will be used with an emergency chlorine gas scrubbing system.

The equipment that was used for ferric chloride storage and dosing to the flash mixers is described below:

- 2 - 27.0 m^3 bulk exterior, above-ground, insulated and heat treated
  fiberglass reinforced plastic tanks
- 2 chemical metering pumps, capacity each 237 L/h at 517 kPa.

Chemical metering pumps are diaphragm, positive displacement units with variable speed SCR drives suitable for automatic quantitative pacing relative to raw water flow for each respective pre-treatment module. Dosage adjustment is manual by setting the length of the pump stroke.

c) Polyaluminum Chloride

In 1985 and 1986, liquid polyaluminum chloride was used on an experimental basis as a primary coagulant and dosed to the flash mixers. The chemical coagulant was used by itself or in conjunction with the other two coagulants, alum and ferric chloride.

One bulk alum storage tank, transfer pump, and Rotodip feeders were used for storing and dosing of the liquid polyaluminum chloride during the trial period.

d) Powdered Activated Carbon

In the original plant design provisions were made for the use of powdered activated carbon slurry for the control of taste and odour. The slurry was to be applied at the flash mixers.

Although none of the mechanical equipment for slurry make-up, mixing and dosing was ever installed, three lined, bulk concrete storage tanks and two unlined tanks, for future use, were provided. Tank capacities are 66.0 m^3 each and measure 3.56 m square by 5.55 m high.

e) Sodium Silicate

As with powdered activated carbon, provisions were made for the future application of activated sodium silicate solution as a coagulant aid to the flash mixers.

Again, no mechanical equipment was installed, but two 66.0 m^3 capacity each, unlined concrete tanks, of similar size to the carbon tanks, were constructed under the original contract in the Chemical Building.

f) Polyelectrolyte Systems

Prior to the plant expansion (1985-1986), a nonionic polyelectrolyte (or polymer) was applied as a filter aid to the head end of the Raw Water Conduits (before filtration).

Facilities for preparing, storing and feeding of the polymer solution included:

- 1 - 1,400 L plastic make-up and storage tank equipped with mechanical mixer
- 2 - diaphragm pumps with variable speed SCR drives.

Pumps were automatically paced proportional-to-flow relative to the respective north and south raw water flow signals. Dosage was set manually by adjusting the pump's stroke length.

These facilities are now no longer used. New polymer application systems have been provided under the recent plant expansion as described below:

i) Coagulant Aid

Facilities are available for application of a cationic polymer solution to the flash mixers as a coagulant aid. System components include the following:

- 1 - dry polymer volumetric feeder with hopper, 600 mm x 200 mm opening and 250 kg storage capacity, the feeder capacity is 1.0 - 1.6 kg/min.
- 1 - hot air blower, piping and polymer wetting disperser
- 1 - 2.74 m dia. FRP mix tank with portable electric mixer, 18.16 m^3 capacity
- 1 - 3.56 m square, lined concrete tank, 66.0 m^3 capacity (original tank provided for activated carbon slurry)
- 2 - 18.0 L/s at 21 m TH, positive displacement, progressive cavity type transfer pumps, 18.7 kW motor operating at 520 rpm
- 3 - 0.1 to 1.4 L/s at 14 m TH, variable speed, progressive cavity type metering pumps, 2 duty and 1 standby, 2.2 kW motor operating at 0 to 520 rpm
- accessories include rotameters and positive displacement flow meters on polymer solution and dilution water, and in-line static mixers for polymer dilution after metering pump.

ii) Filter Aid

A filter aid system is available for the application of a nonionic polymer to the Raw Water Conduits upstream of the filters. System components include the following:

- 1 - dry polymer volumetric feeder with hopper, 600 mm x 200 mm opening, and 250 kg storage capacity, the feeder capacity is 1.0 to 1.6 kg/min.
- 1 - hot air blower, piping and polymer wetting disperser
- 1 - 1.52 m dia. FRP mixing tank with portable electric mixer, 4,540 L capacity
- 1 - 2.74 m dia. FRP solution storage tank, 22.7 m^3 capacity
- 2 - 1.0 L/s at 10 m TH, positive displacement, progressive cavity type transfer pumps, 1.5 kW motor operating at 360 rpm
- 3 - 0.1 to 0.3 L/s at 14 m TH, variable speed, progressive cavity type metering pumps, 2 duty and 1 standby, 1.1 kW motor operating at 0 to 400 rpm
- accessories include rotameters and positive displacement flow meters on polymer solution and dilution water, and in-line static mixers for polymer dilution after metering pump.

iii) Dewatering Aid

A sludge dewatering aid system is available for the application of an anionic polymer to the feed stream at the inlet of the centrifuges. System components include the following:

- 1 - dry polymer volumetric feeder with hopper, 600 mm x 200 mm opening, and 250 kg storage capacity, the feeder capacity is 1.0 to 1.6 kg/min.
- 1 - hot air blower, piping and polymer wetting disperser
- 1 - 1.98 m dia. FRP mixing tank with portable electric mixer, 6,810 L capacity
- 1 - 2.44 m dia. FRP solution storage tank, 13.62 m^3 capacity
- 2 - 6.4 L/s at 10 m TH, positive displacement, progressive cavity type transfer pumps, 7.5 kW operating at 520 rpm
- 3 - 0.1 to 0.6 L/s at 14 m TH, variable speed, progressive cavity type metering pumps, 2 duty and 1 standby, 1.1 kW motor operating at 0 to 600 rpm
- accessories include rotameters and positive displacement flow meters on polymer solution and dilution water, and in-line static mixers for polymer dilution after metering pump.

iv) System Description and Control

Polymer systems are suitable to handle either of the available polymer types, cationic, nonionic or anionic. Systems are specifically designed to handle dry polymer products delivered in bag form. But provisions were made also to receive, store and dilute polymer purchased in concentrated liquid or emulsion form.

For the purpose of design all systems were sized as follows:

System	Average Polymer Dosage	Solution Concentration
Coagulant Aid	372.7 kg/d	0.2%
Filter Aid	37.3 kg/d	0.2%
Dewatering Aid	86.4 kg/d	0.2%

The dry polymer make-up systems are fully automated and will function until the dry chemical feeder hopper is empty. Manual override controls are available for all major functions. Instrumentation equipment is mounted in local control panels for the respective systems.

Level controls are available on all mixing tanks and solution storage tanks. Level control signals are 4 - 20 mA and basically serve to start and stop equipment - volumetric feeders, mechanical mixers, transfer pumps, initiate low and high level alarms, and provide level indication for solution storage tanks.

Polymer solution feed pumps are provided with local/remote controls with speed indication and remote status indication in the South Polymer Room for coagulant aid feed pumps. The operation of coagulant aid and filter aid feed pumps is automatically controlled or paced by a flow signal from either the main north or south raw water flow meter. The sludge dewatering aid feed pumps are controlled and automatically paced by the calculated flux of solids to the centrifuge. The polymer dosage is set manually by adjusting the pump speed.

g) Caustic Soda

During the recent plant expansion, facilities were provided for dosing of liquid caustic soda solution to the discharge of the Filtered Water Conduits. The purpose of adding caustic soda to the process stream is twofold; firstly, for pH adjustment in order to reduce the aggressive tendency of the treated water and secondly, for counteracting the pH depression that occurs during postchlorination in order to eliminate the post-precipitation of aluminum.

Storage and feed equipment available include the following:

- 2 - 3.56 m square, bulk concrete storage tanks, lined for corrosion protection, 66.0 m^3 capacity each (these are existing tanks that were originally provided for future activated carbon storage)

- 3 - 2.12 L/min. at 28 m TH, cam drive, diaphragm, double head metering pumps, 2 duty and 1 standby, 125 watt motor with a variable speed DC/SCR controller, and operating at 0 to 120 spm (strokes per minute)
- accessories include dilution water supply line to bulk storage tanks with 40 mm dia. positive displacement flow meter.

Chemical metering pumps are equipped with automatic quantitative controls for pacing relative to either north or south raw water flow signals. Qualitative dosage control is achieved by manually adjusting the pump stroke.

C.4.2 GASEOUS CHEMICAL FEED EQUIPMENT

a) Chlorine Gas

Chlorine gas in solution form is applied for prechlorination and postchlorination.

Application points are:

- prechlorination:
  1) surge well of Low Lift Pumping Station
  2) north and south Flash Mixers
  3) north and south Raw Water Conduits (when bypassing pre-treatment)
- postchlorination:
  1) outlet end of Filtered Water Conduits #1 and #2.

Storage Equipment

Liquid chlorine gas under pressure is stored in 908 kg. containers in the Storage Room of the Chlorine Building. Space is available for a single tier of 19 containers, 16 in inventory and 3 in service on weigh scale.

The weigh scale consists of a 3 - 908 kg container mechanical scale with dial cabinet and 500 mm dia. circular dial.

Chlorinators

The plant has three chlorinators of the solution feed, vacuum type, one for prechlorination service and two for postchlorination service. Space is available for the addition of one future chlorinator. Machine capacities are as follows:

- pre-chlorinator: 908 kg/d capability with 454 kg/d rotameter rating
- post-chlorinator: 908 kg/d capability each, with 227 kg/d rotameter rating.

Chlorinators have electric plug positioners for automatic pacing relative to flow.

The pre-chlorinator dosage is manually set and automatically controlled with respect to total raw water flow. Application of chlorine solution to the Flash Mixers or the Raw Water Conduit is metered by rotameters to provide for proportional distribution by means of throttling valves.

Individual post-chlorinators are used for dosing of chlorine solution to the Filtered Water Conduit No. 1 and No. 2. The dosage is manually set on each chlorinator and automatically controlled with respect to each respective total filter bank flow.

In the event of post-chlorinator or ejector failure, either of the remaining chlorinators can be paced by the desired summated filter flow signal.

Chlorine Residual Analyzer

One amperometric type analyzer was provided with the original plant for continuously measuring the chlorine residual of a water sample from the common discharge header of the plant output. The analyzer however has not been functioning for the past three or four years and a new unit by the Hach Company using the DPD method of analysis has been purchased and will be installed later in 1988.

The original analyzer instrumentation includes local indication, high/low chlorine residual alarms, signal transmission to indicating recorder and alarm annunciator on Main Control Panel.

Gaseous Chemical Control Accessories

Gaseous chemical control accessories include:

- 1 local gaseous chemical control panel
- 1 amperometric titrator for calibration and for operation check
- 1 chlorine-in-air gas detector mounted on the Chlorine Instrument Panel; the chlorine gas detector functions to sound an alarm in case of chlorine leakage in the Chlorine Equipment Room and the Chlorine Storage Room
- visual alarm annunciator with transmission to the Main Control Panel and activation of warning light outside Chlorine Room
- 3 flow indicators mounted on the Chlorine Instrument Panel and signal selector switch.

A caustic soda chlorine gas scrubbing system is scheduled to be installed later in 1988.

C.5 SAMPLING

Sample pumps are of the single stage peripheral turbine type installed to deliver continuously flowing water samples to the following locations and instruments:

- the sample sink in the Plant Laboratory located in the Administration Building
- the sample sink in the Process Monitoring Room located in the new plant expansion
- on-line monitors consisting of turbidity meters and a chlorine residual analyzer, when in service.

Sample pump specifications and information on sampling points, piping sizes, flow velocities and travel times to the point of discharge are presented in Tables C.9 and C.10. It will be noted that travel times to analyzers range from 0.7 to 2.1 minutes and those to sample sinks from 0.4 to 6.4 minutes.

TABLE C.9

SAMPLE PUMPS

Location Sampling Services	Sampling Point	Pump #	Rated Capacity Flow, L/s	Head, m	Rating, kW
Chemical Building					
- 1060 Ø North Raw Water Supply	1	SP-1	0.22	30.3	0.37
- 1370 Ø South Raw Water Supply	2	SP-1	0.22	30.3	0.37
Chemical Building					
- North Raw Water Conduit (Settled Water)	3	SP-2A[1]	0.13	10	0.09
- South Raw Water Conduit (Settled Water)	4	SP-2B[1]	0.13	10	0.09
Filter Building-Pipe Gallery					
- Filter Water Conduit #1	5	SP-3	0.25	26.0	0.37
- Filter Water Conduit #2	6	SP-3	0.25	26.0	0.37
Plant Output Meter Chamber					
- 1060 Ø Discharge Header #1	7	PRV[2]	0.25	240 kPa	-
- 1060 Ø Discharge Header #2	8	PRV	0.25	240 kPa	-

[1] Original pump SP-2 was replaced by pumps SP-2A and SP-2B under recent expansion

[2] PRV denotes pressure reducing valve

SAMPLE PIPING CHARACTERISTICS

Location Sampling Service	Sampling Point	Suct./Disch. Piping, mm	Pipe Length, m Suct./Disch.	Disch. Point	Velocity, m/s Suct./Disch.	Total Travel Time, min.
Chemical Building						
- 1060 Ø North Raw Water Supply	1	25-20/20	17-5/122	Lab	0.43-0.67/0.67	3.8
			17-11/-	$A-TU_1$	0.43-0.67/-	0.9
			17-5/44	PMR	0.43-0.67/0.67	1.9
- 1370 Ø South Raw Water Supply	2	25-20/20	9-4/122	Lab	0.43-0.67/0.67	3.5
			9-15/-	$A-TU_1$	0.43-0.67/-	0.7
			17-5/44	PMR	0.43-0.67/0.67	1.9
Chemical Building						
- North Raw Water Conduit (Settled Water)	3	20/20	32/122	Lab	0.40/0.40	6.4
			32/18	$A-TU_2$	0.40/0.40	2.1
			32/44	PMR	0.40/0.40	3.2
- South Raw Water Conduit (Settled Water)	4	20/20	23/122	Lab	0.40/0.40	6.0
			23/18	$A-TU_2$	0.40/0.40	1.7
			23/44	PMR	0.40/0.40	2.8
Filter Building - Pipe Gallery						
- Filter Water Conduit #1	5	20/20	6/60	Lab	0.76/0.76	1.4
- Filter Water Conduit #2	6	20/20	7/60	Lab	0.76/0.76	1.5
Plant Output Meter Chamber						
- 1060 Ø Discharge Header #1	7	-/20-13	-/3-27	Lab	-/0.76-1.36	0.4
			/3-51	$A-TU_3$	-/0.76-1.36	0.7
Plant Output Meter Chamber						
- 1060 Ø Discharge Header #2	8	-/20-13	-/6-27	Lab	-/0.76-1.36	0.5
			-/6-51	$A-TU_3$	-/0.76-1.36	0.8
			-/6-134	$A-Cl_2$	-/0.76-1.36	1.8

Note

Sample pipes are made of PVC plastic.

Legend

Lab = Plant Laboratory - Sample Sink
$A-TU_1$ = Analyzer - Turbidimeter 1
$A-Cl_2$ = Analyzer - Chlorine Residual
PMR = Process Monitoring Room - Sample Sink

Pumps are constructed of cast iron casings and have cast bronze impellers. Sample pipes are all of PVC plastics and have solvent welded joints.

C.6 PROCESS AUTOMATION

The original London (Lake Huron) Water Treatment Plant was equipped with a complete analogue supervisory and control system. The automatic process control system is of the distributed type where field equipment is hard wired to area control panels which contain logic elements, and only selected signals are carried back to the Main Control Panel. A microwave radio system and telemetering equipment also were provided for receiving and sending status and control signals from the Main Control Room at the plant to the Arva Terminal Reservoir and Pumping Station, and the Ausable Reservoir and Booster Pumping Station.

Instrumentation for manual operation was provided as an alternative to each automatic control system.

During the initial years of operation the plant could be operated in an automatic mode. In more recent years, with increasing water demands and more frequent backwashing of filters, the original algorithm for low lift pump control has caused low lift pump cycling and rapid changes in treatment rate. Also, it became more and more difficult to maintain the analogue instrumentation because of unavailability of replacement parts. For these and other reasons, the treatment plant is now essentially operated on a manual basis. Partial automatic control is still used for the operation of the low lift pumps, filters, backwash program which controls the wash water pumps, and the service water pumps. The flow of water in the treatment plant is used to pace chemical addition systems and, following the plant expansion and upgrading, the sludge recycle pumps.

New automatic control equipment installed during the plant expansion and upgrading includes C-M-A controllers for the operation of sludge recirculation and sludge waste pumps. Remote speed control systems also have been provided for the waste pumps and the dewatering aid polymer pumps. All instruments and control loops are designed to incorporate a future computer for plant control.

In general, the plant is operated in accordance with the following design concepts:

1. The control objective is to supply the demand for treated water, measured as withdrawal from the Arva Terminal Reservoir. This is achieved by pacing each pumping or flow control unit by conditions immediately downstream of the unit.

2. The treated water pumps control concept, in manual or automatic mode, is based on a level measurement at the Arva reservoir.

3. With the construction of the Ausable Booster Pumping Station, booster pumps are controlled, in manual or automatic mode, based on level in the Arva reservoir. Treated water pumps then are controlled from level in the Ausable reservoir.

4. For energy conservation reasons, it has been found that it is practical to operate the high lift pumps and booster pumps manually. Booster pumps are selected to meet the demand at Arva and high lift pumps are operated to match the booster pumps.

5. Filters operate at constant rate controlled by a filter rate controller. The control of the filter rate is manual or automatic. In the automatic mode the filter rate controllers respond to a rate-setting signal derived from changes of clear well water level over the designated operating band of 760 mm.

6. Facilities were provided for filter backwashing either on a manual basis or from a manually initiated automatic program in response to an automatic annunciation of high head loss or end of run based on time in service.

7. With the higher plant flow rates, experience has shown that the master filter rate control system is sensitive to rapid drawdown of the clear well resulting in surges in filter rate and cycling of the low lift pumps. For these reasons filters are operated in the manual mode during filter washing operations.

8. The low lift pumps are automatically controlled from the Low Lift Area Central Control Panel. The control function is based on water level in the Raw Water Conduit and filter rate. Pump operation will respond to changes of water level in the conduit over the designated operating band of 460 mm. The filter rate is used to determine the number of pumps in service.

9. Facilities for manual operation of low lift pumps are available at the Central Control Panel or the Main Control Panel.

10. Emergency manual operation of pumps for maintenance purposes is conducted locally at the equipment.

11. Chemical feed systems are designed for automatic pacing of dosages relative to flow, while qualitative adjustment of feeders for dosage setting is done manually.

A listing of the instrumentation hardware available at the plant is given below:

Low Lift Pumping Station

- surge well level measurement
- surge well temperature measurement
- raw water travelling screen differential level control panel
- pump wet well level measurement
- local pump control panels and Central Control Panel.

Treatment Plant

- flow measuring equipment for raw water in each pre-treatment module, filter effluent, plant output as well as filter wash water and plant service water
- water level measuring equipment for Raw Water Conduits and Clear Well
- supervisory control panel
- main control panel with Analogue Computing Device
- local area control panels

- individual filter consoles and central filter control desk
- automatic filter backwash program
- sludge handling control panels
- C-M-A controllers for sludge recirculation and sludge waste pumps
- speed control for sludge waste pump and dewatering aid polymer pumps
- centrifuge local control panels
- flow measuring equipment for sludge recirculation and waste flow-measuring equipment for process parameters - streaming current detectors, tubidity meters, filter loss of head
- PC controller for on-line scanning and recording of turbidity data
- sample pump control

Chemical Systems

- local control panels for chemical preparation, transfer and feeding equipment
- proportional-to-flow controllers for pacing of chemical feed pumps, chlorinators and sludge recirculation pumps
- chlorine instrument panel
- chlorine gas-in-air detector
- chlorine residual

High Lift Pumping Station

- suction conduit level alarm with low level pump lockout contact
- local pump control panels, high lift pumps, wash water pumps, service water pumps
- high lift pump controls including discharge valve
- wash water and service water pump controls
- pressure measuring equipment
- hydro-pneumatic tank level measurement and alarm equipment
- air compressor controls and local control panel
- telemetering control panel
- PC controller for the Ausable and Arva reservoirs and pumping stations

C.7 EMERGENCY STANDBY OPERATION

In the event of a power failure all plant operations are shut down with the exception of one 80 L/s capacity service water pump which is powered by direct diesel engine drive. One standby diesel generator (plus one to be installed in 1988) provide power for essential services only including instrumentation equipment, emergency lighting and operation of sump pumps.

C.8 DRAWINGS

a) Plant Drawings

Included in this report are two drawings as follows:

1) Ministry of the Environment
   Project No. 5-0001-02
   Dwg. No. G1 of 5 - Location and Site Plan

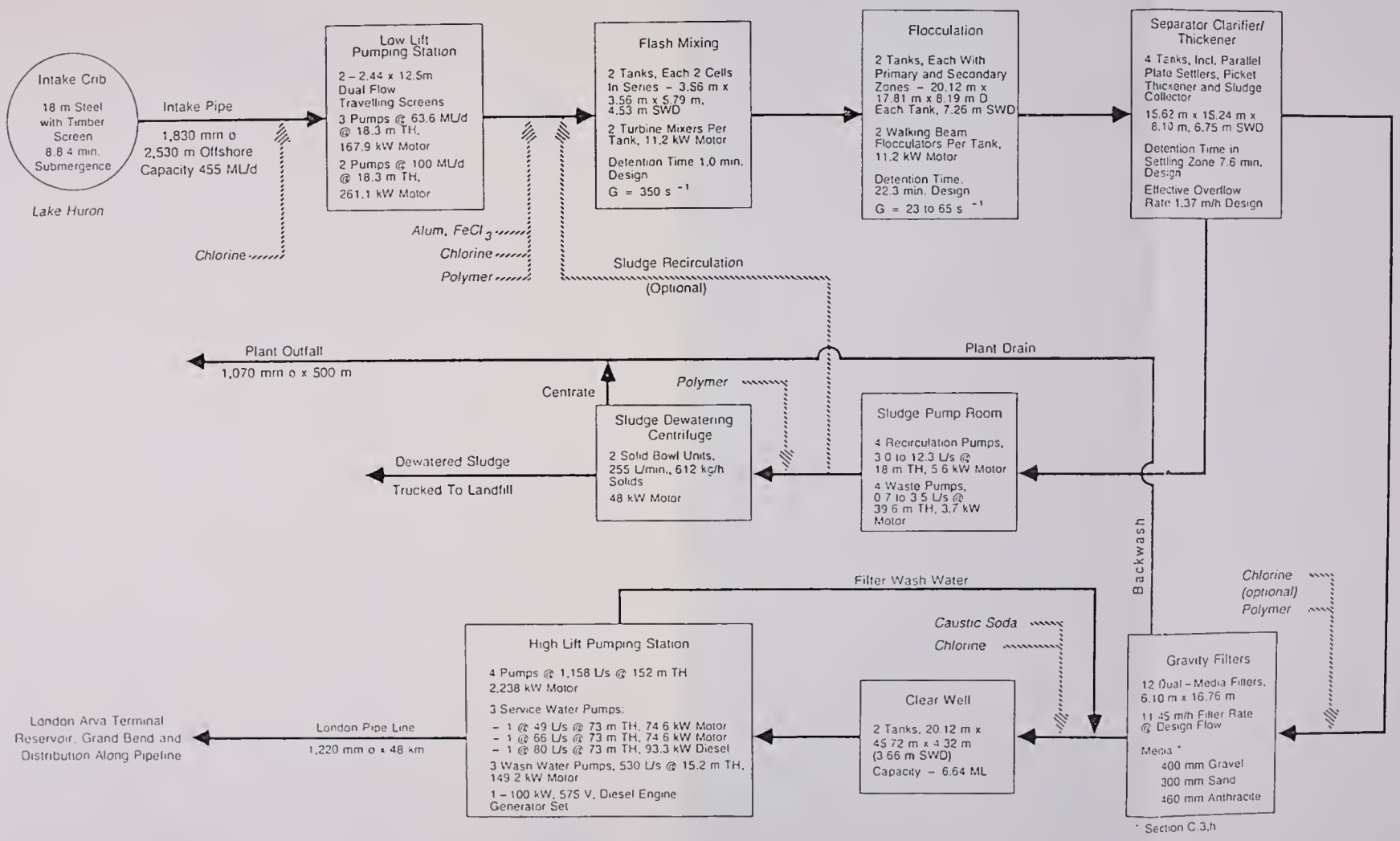
2) Ontario Water Resources Commission
   Project No. OWRC-WP-64-1
   Dwg. No. 151 of 163 - Instrumentation Schematic

b) Process Design Schematic

Figure C.2 presents a process design schematic of the London (Lake Huron) Water Treatment Plant.

c) Plant Photographs

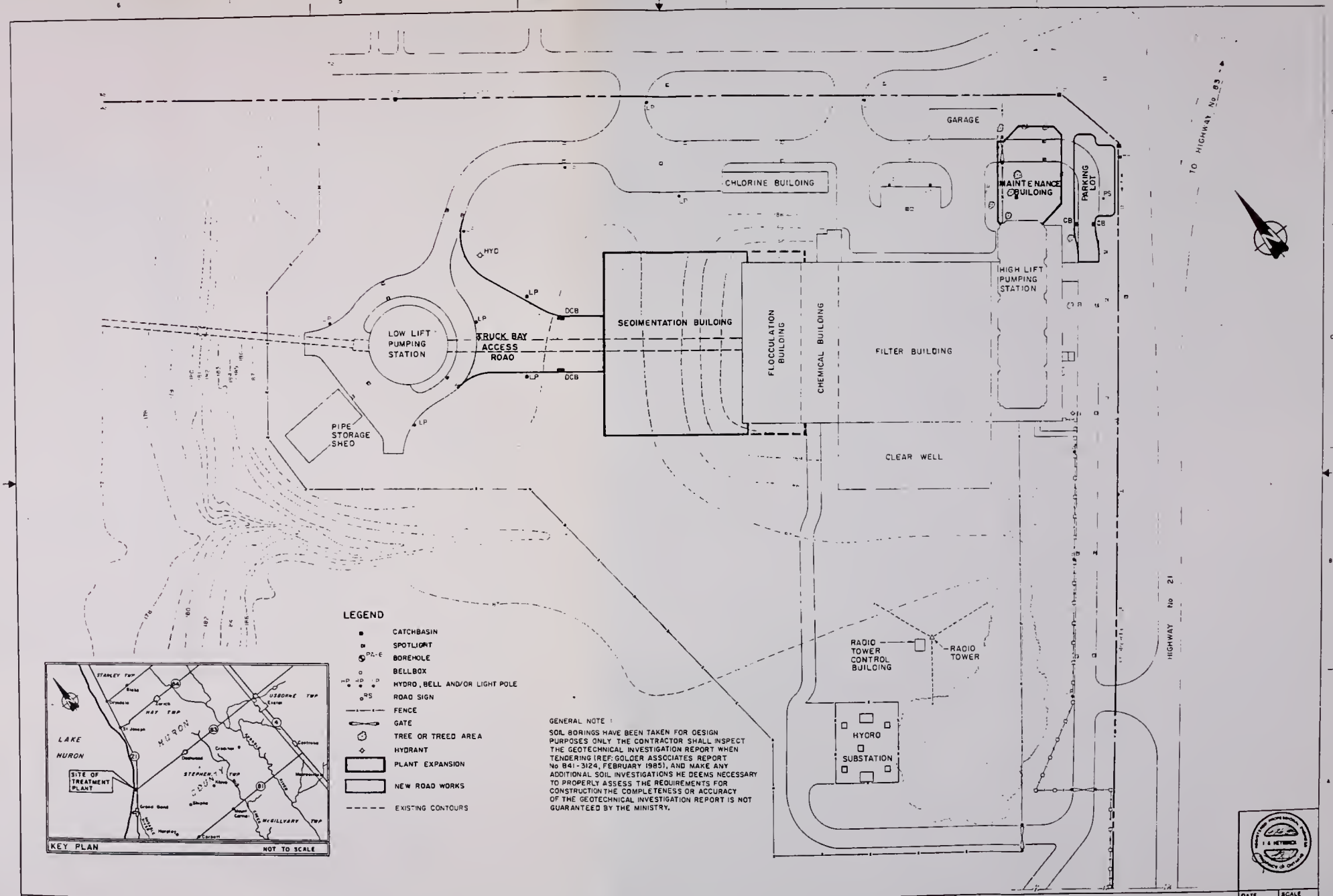
A photographic record of the plant is included in this report following Figure C.2. The record is preceded by a photograph index.



Legend: Design Capacity – 336,400 m^3/d
SWD – Side Water Depth

48079

Figure C.2
LONDON (LAKE HURON) WATER TREATMENT PLANT
Process Design Schematic



No	REVISIONS	DATE	INTLS	MICROFILM ROLL No. DR-	DRAWN BY JBB	DESIGNED BY JAH	Maclaren Engineers	Ontario	MINISTRY OF THE ENVIRONMENT PROJECT No. 5-0001-02	LAKE HURON WATER SUPPLY SYSTEM TREATMENT PLANT EXPANSION AND UPGRADING CONTRACT 4 SEDIMENTATION AND MAINTENANCE FACILITIES
	AS CONSTRUCTED	Nov86	RAL		CHECKED BY JAH	APPROVED BY BLW				

GENERAL

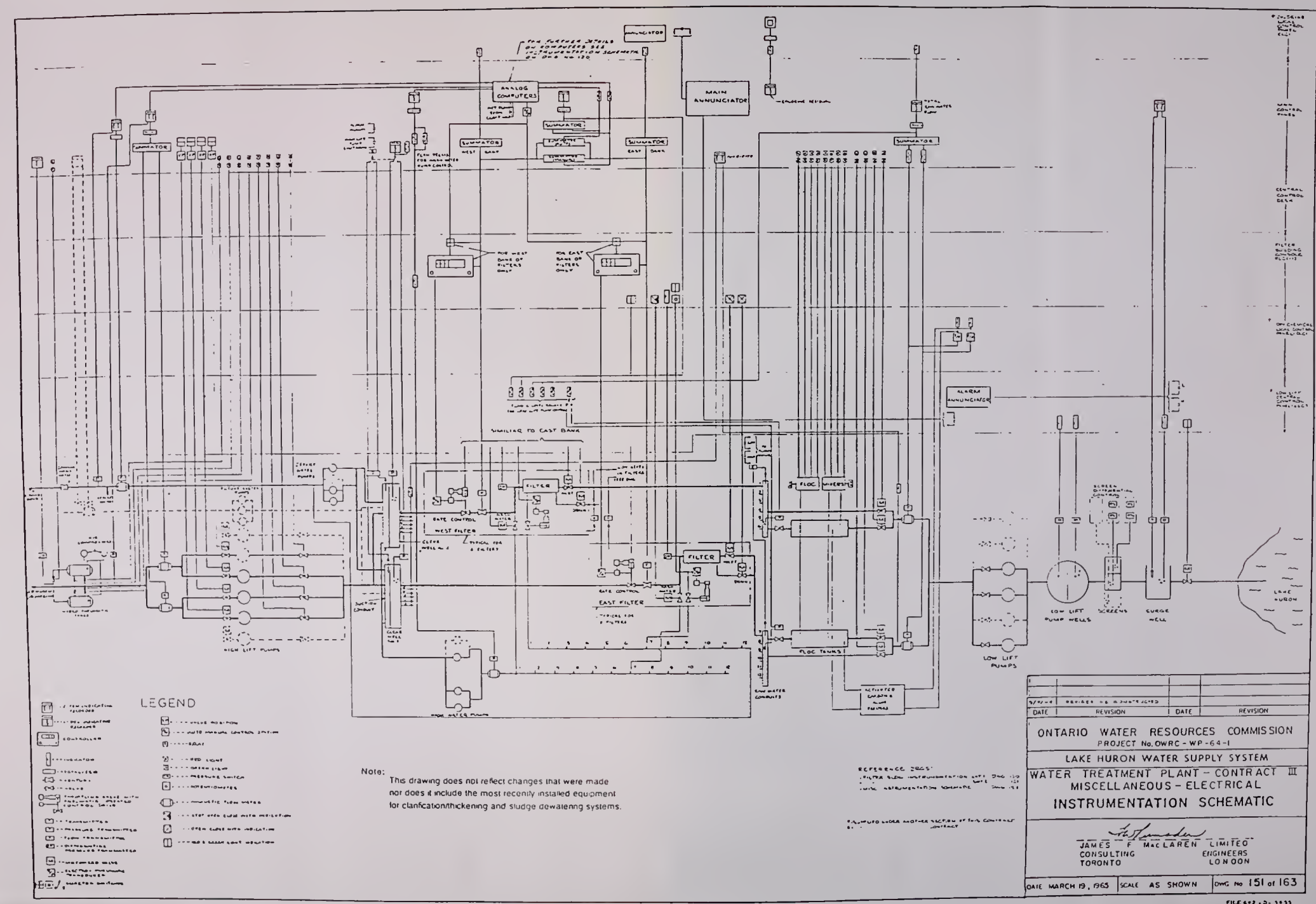
LOCATION AND SITE PLAN

DATE JUNE, 1985 | SCALE 1 500

DRAWING No. G1 of 5

G01 82

FILE 34925-1002-A1


ANALOG COMPUTERS
MAIN ANNUNCIATOR
SUMMATOR
SUMMATOR WEST BANK
SUMMATOR EAST BANK
SUMMATOR
ALARM ANNUNCIATOR
SIMILAR TO EAST BANK
FILTER
GATE CONTROL
WEST FILTER
EAST FILTER
FLOC
MIXERS
FLOC TANKS
HIGH LIFT PUMPS
LOW LIFT PUMPS
LOW LIFT PUMP WELLS
SCREENS
SURGE WELL
LAKE HURON
LEGEND
Note:
This drawing does not reflect changes that were made nor does it include the most recently installed equipment for clarification/thickening and sludge dewatering systems.
DATE
REVISION
DATE
REVISION
ONTARIO WATER RESOURCES COMMISSION
PROJECT No. OWRC - WP - 64 - 1
LAKE HURON WATER SUPPLY SYSTEM
WATER TREATMENT PLANT - CONTRACT III
MISCELLANEOUS - ELECTRICAL
INSTRUMENTATION SCHEMATIC
JAMES F MACLAREN LIMITED
CONSULTING ENGINEERS
TORONTO LONDON
DATE MARCH 19, 1965
SCALE AS SHOWN
DWG No 151 of 163

PHOTOGRAPHIC RECORD

Lake Huron Water Supply System

Photograph Index

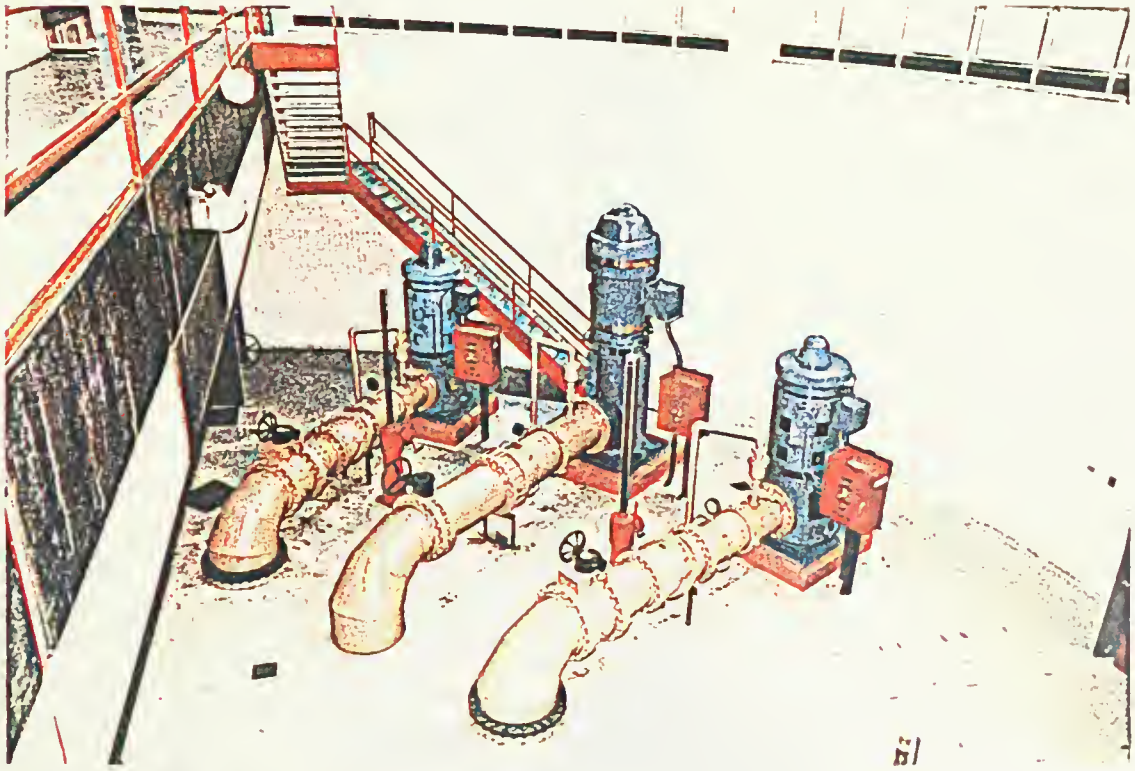
Photograph	Subject
1	London (Lake Huron) Water Treatment Plant - Southeast Elevation
2	Rear View of New Clarifier and Sludge Dewatering Building - Northwest Elevation
3	Low Lift Pumping Station
4	Low Lift Pump Room Floor
5	Low Lift Pump and Discharge Piping
6	Low Lift Pump Control Panel
7	Raw Water Travelling Screen
8	Chemical Building Gallery No. 1 - Sample Pump Station
9	Chemical Building Gallery No. 1 - Coagulant Aid Polymer Metering Pumps
10	Chemical Building Gallery No. 1 - Caustic Solution Metering Pumps
11	Chemical Building Gallery No. 3 - Rotodip Alum Solution Feeders
12	Vertical Turbine Flash Mixer
13	Flocculator Drive Unit
14	Flocculation Tank - Walking Beam Flocculators
15	Parallel Plate Clarifier and Thickener
16	Water Treatment Polymer Room South - Coagulant Aid and Filter Aid Polymer Equipment

Photograph	Subject
17	Sludge Pump Room - 1 Recirculation Pump and 2 Sludge Waste Pumps
18	Centrifuge Room - Sludge Dewatering Solid Bowl Centrifuge and Controls
19	Sludge Handling Control Panel
20	Filter Operating Gallery
21	Filter Control Console
22	Filter Pipe Gallery - Effluent Piping and Control Valve
23	Main Pipe Gallery in Flocculation Building - Turbidity and Streaming Current Analyzers
24	Chlorine Building
25	Chlorine Storage Room - 3 Ton Container Weigh Scale
26	Chlorine Equipment Room - 1 Prechlorinator and 2 Postchlorinators
27	High Lift Pump Room Floor
28	High Lift Pump
29	Filter Wash Water Pump
30	Laboratory
31	Control Room

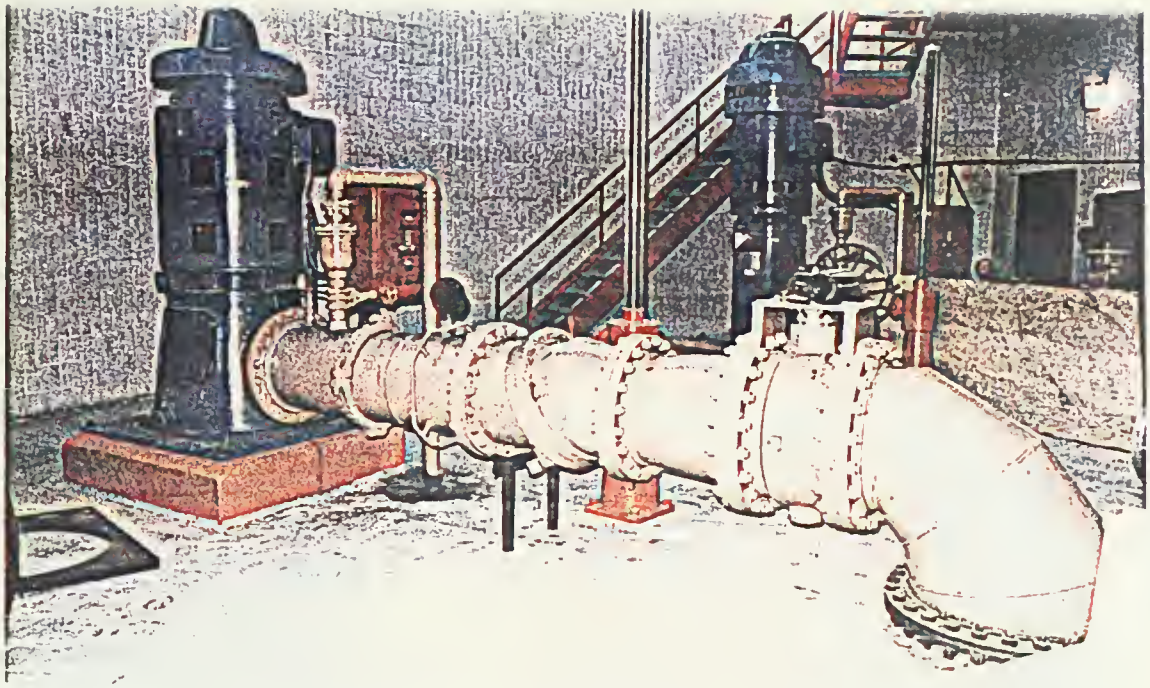
1. London (Lake Huron) Water Treatment Plant
   - Southeast Elevation

2. Rear View of New Clarifier and Sludge Dewatering
   Building - Northwest Elevation

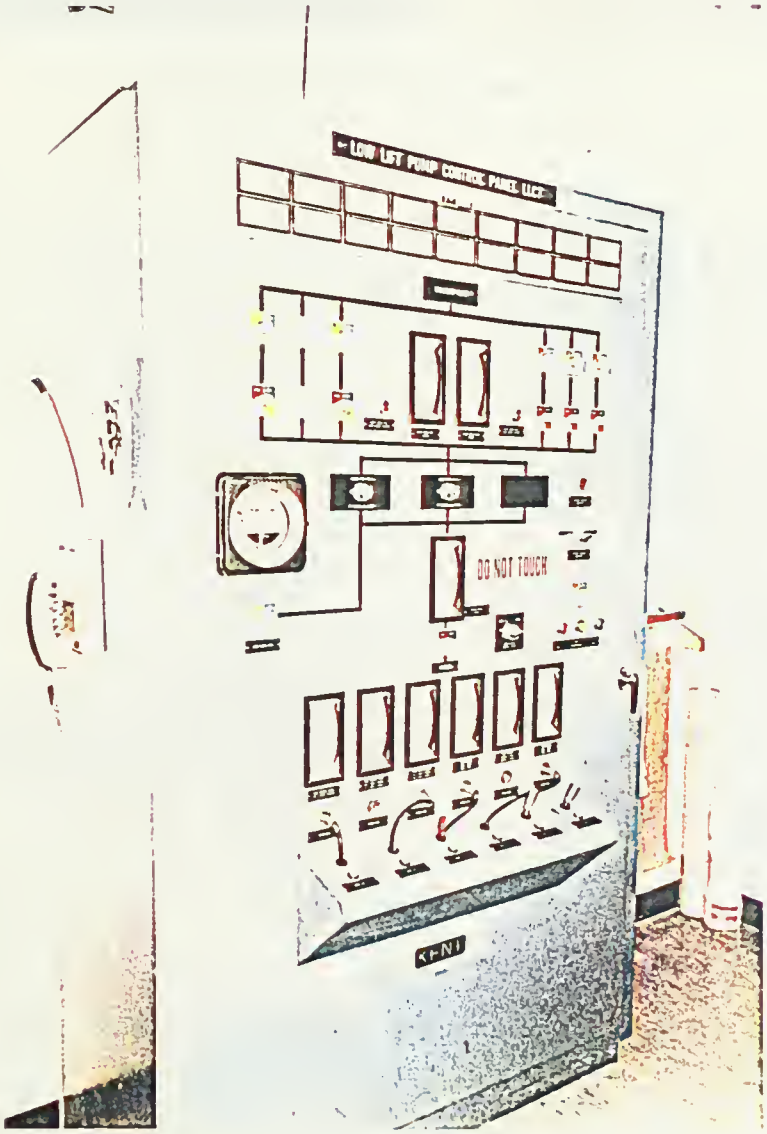
3. Low Lift Pumping Station



4. Low Lift Pump Room Floor

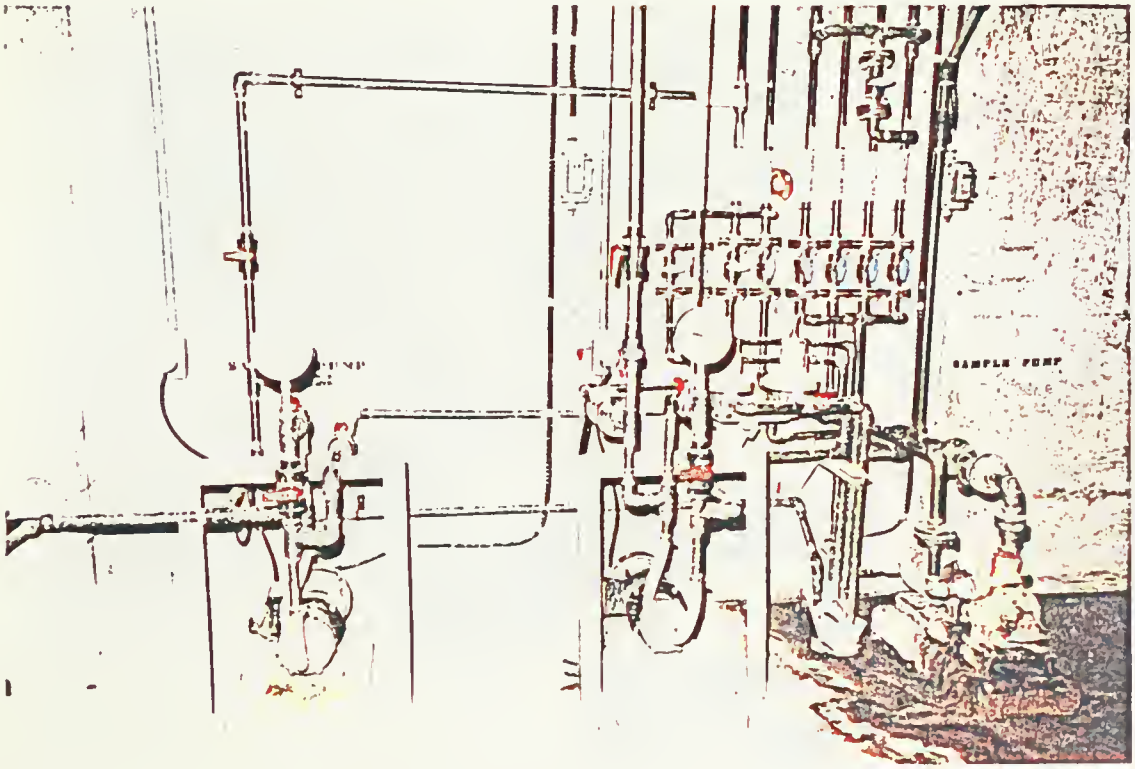


5. Low Lift Pump and Discharge Piping



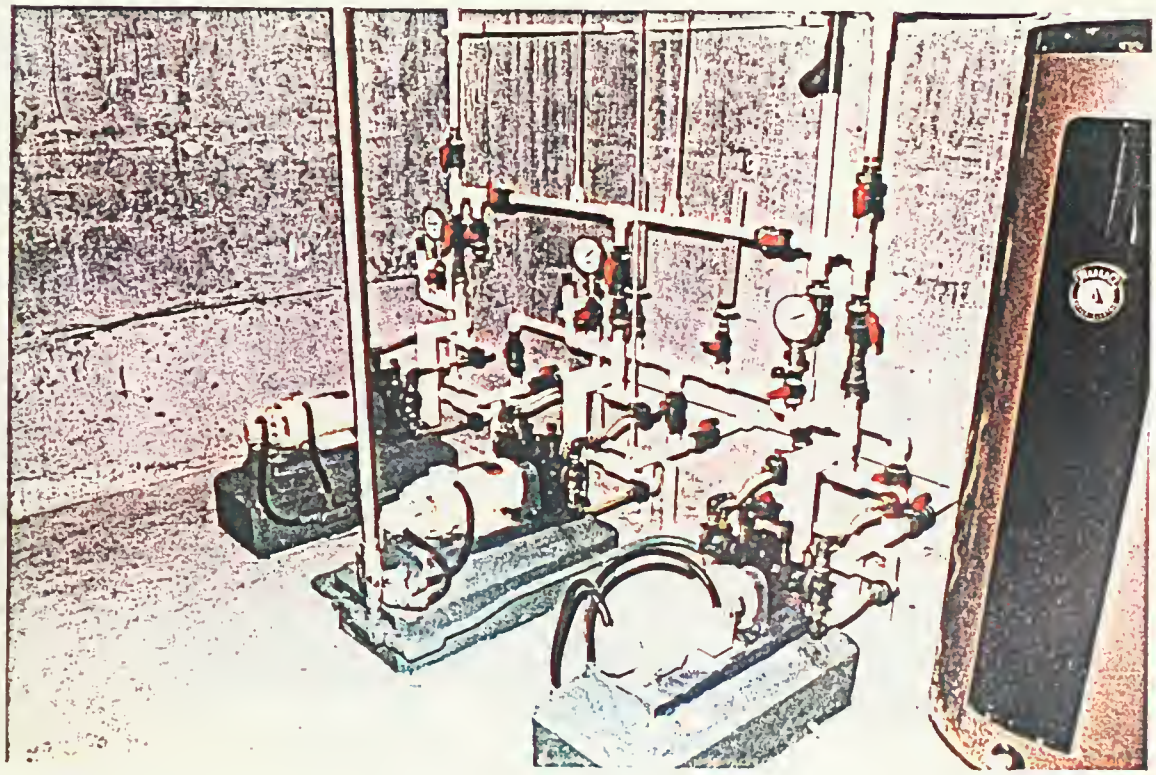
6. Low Lift Pump Control Panel

7. Raw Water Travelling Screen

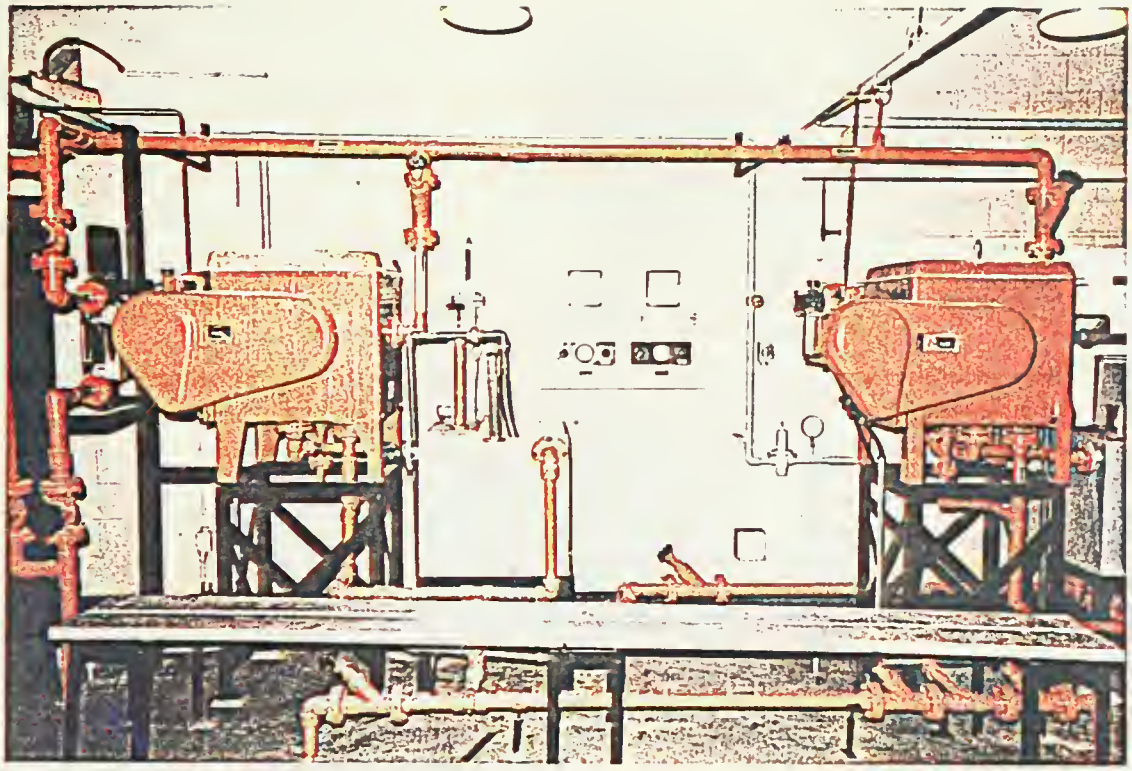


8. Chemical Building Gallery No. 1 - Sample Pump Station

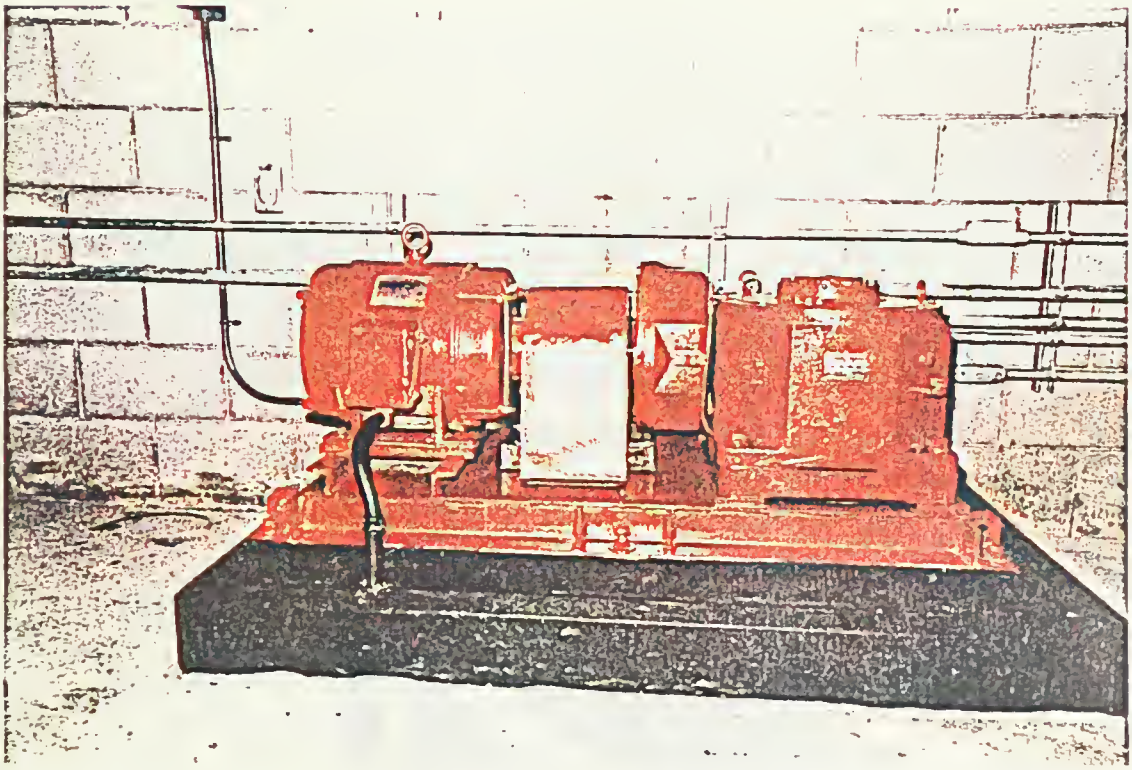
9. Chemical Building Gallery No. 1 - Coaguland Aid Polymer Metering Pumps



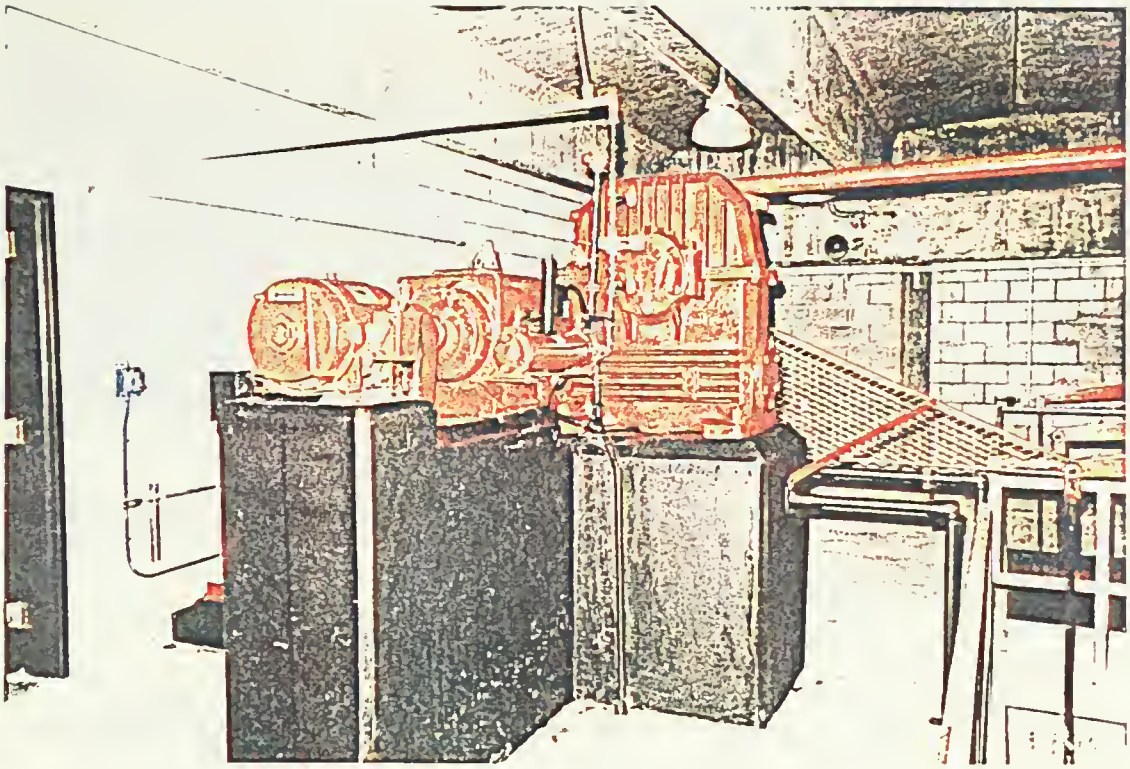
10. Chemical Building Gallery No. 1 - Caustic Solution Metering Pumps



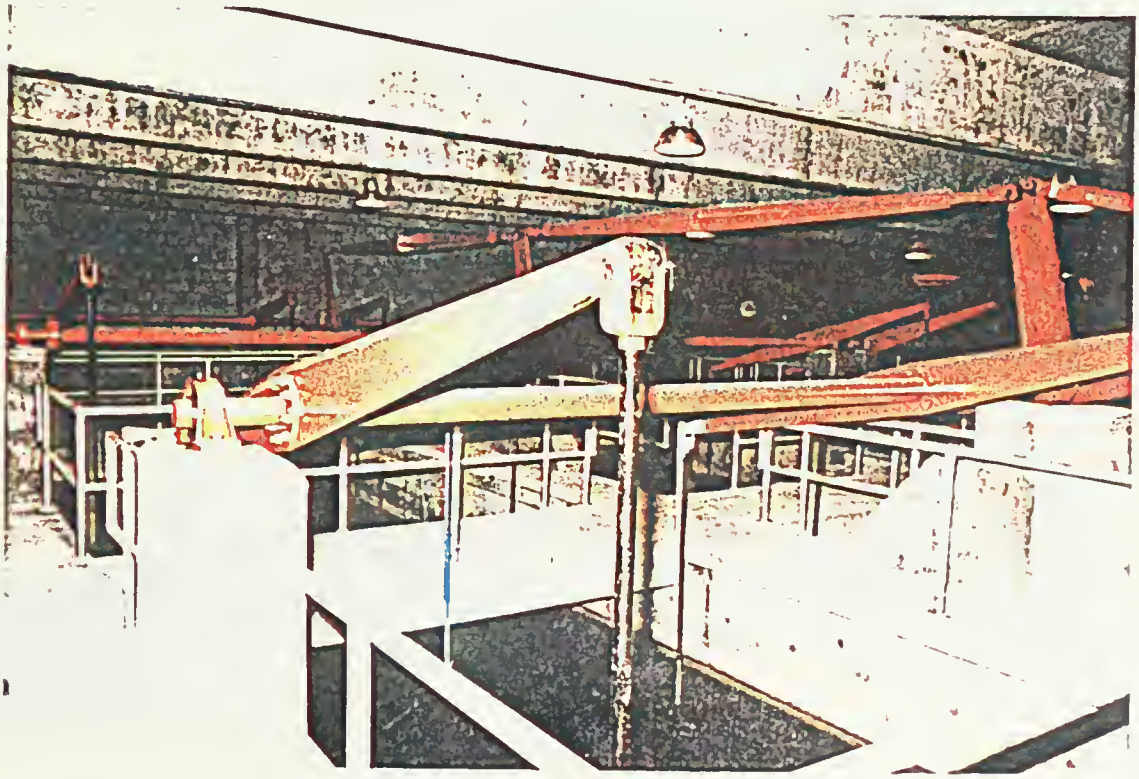
11. Chemical Building Gallery No. 3
- Rotodip Alum Solution Feeders



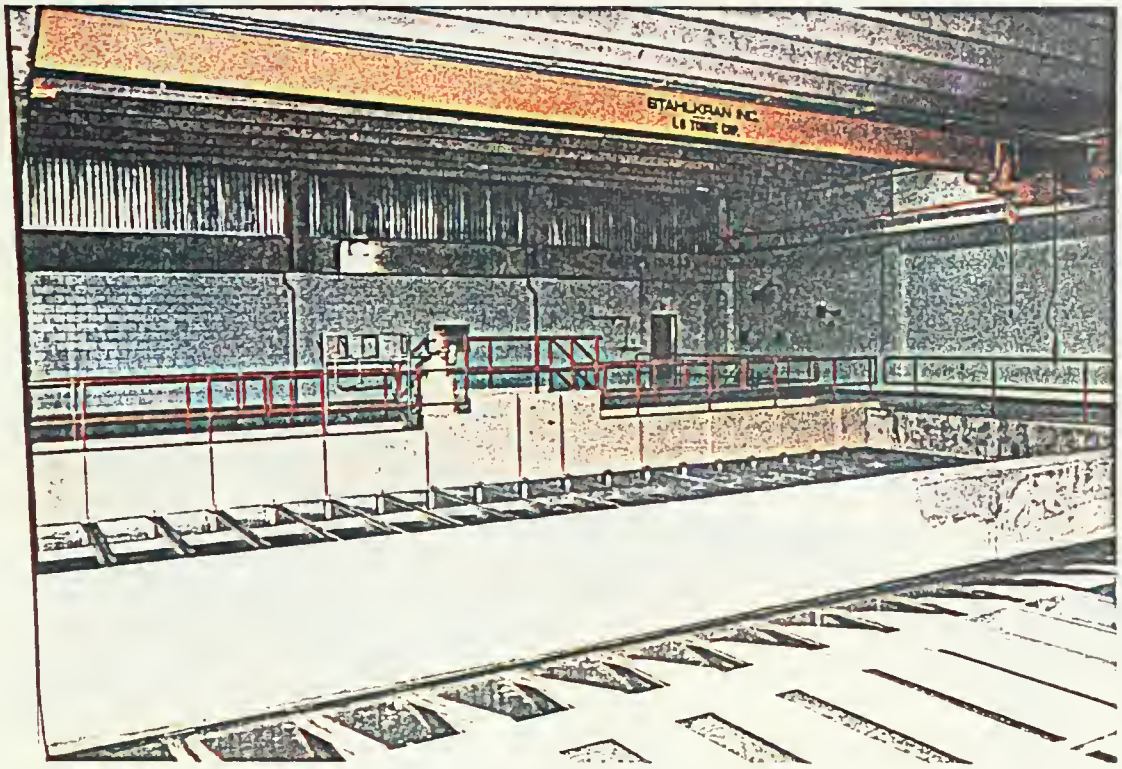
12. Vertical Turbine Flash Mixer



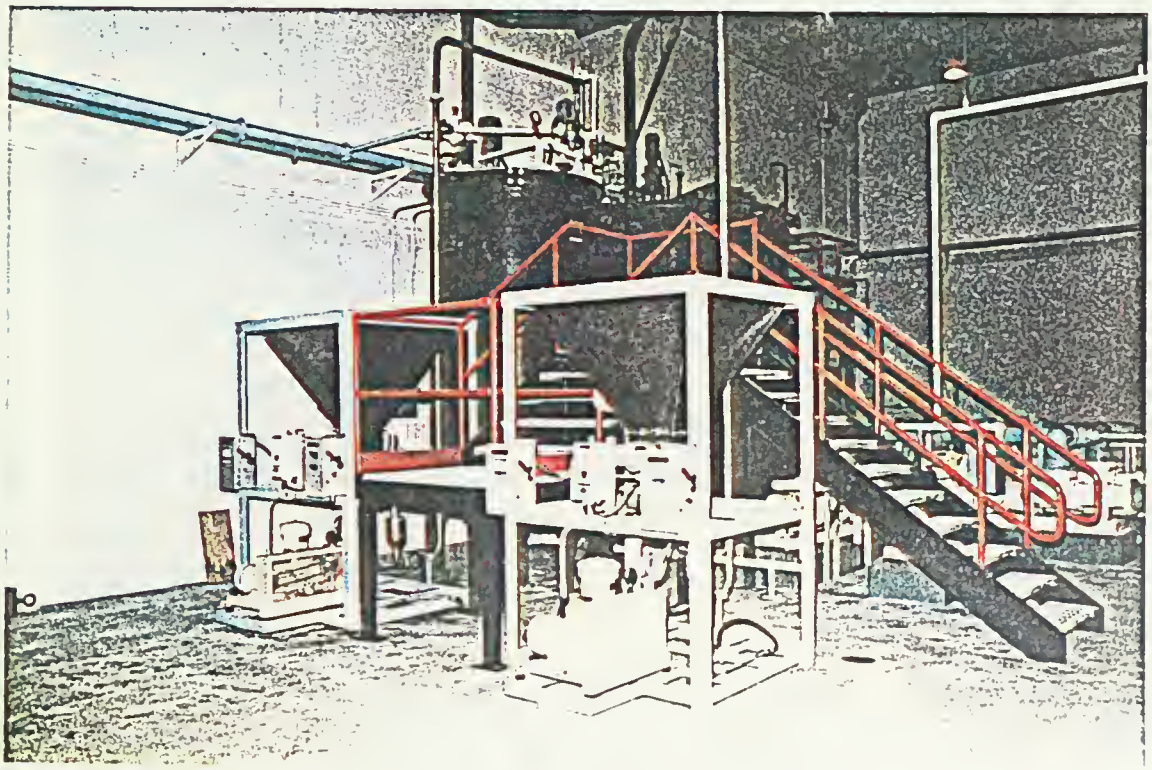
13. Flocculator Drive Unit



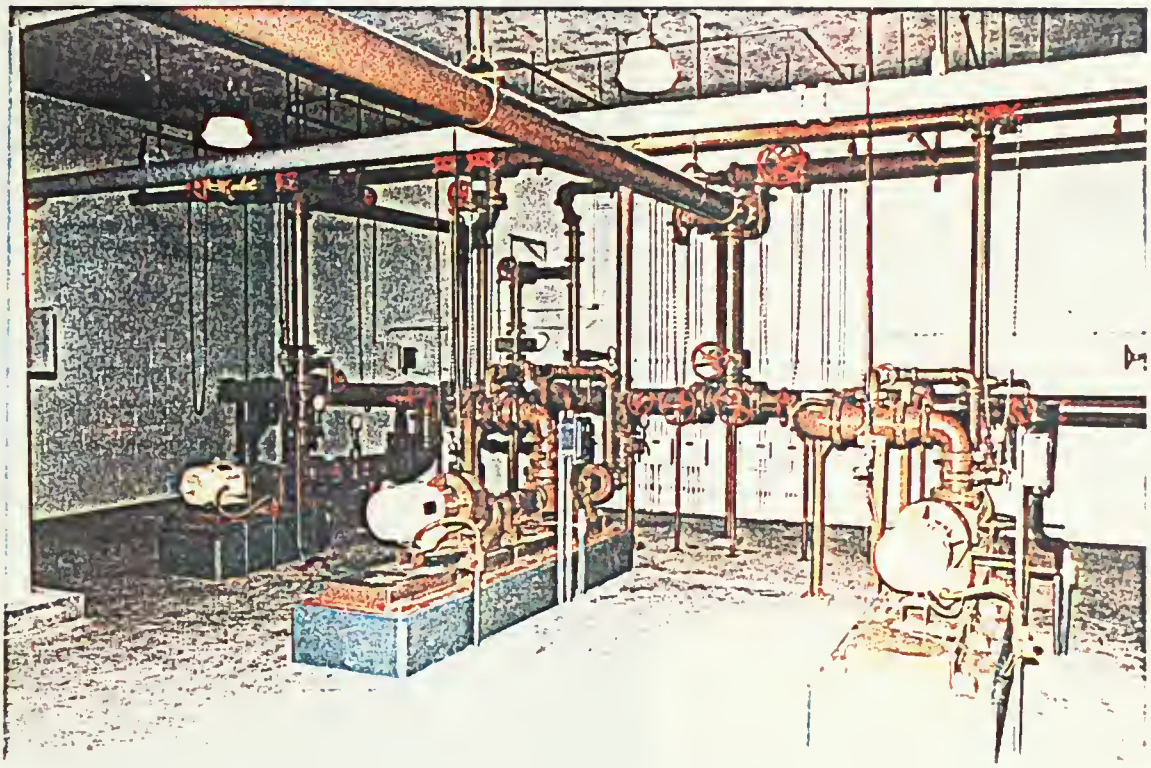
14. Flocculation Tank
- Walking Beam Flocculators



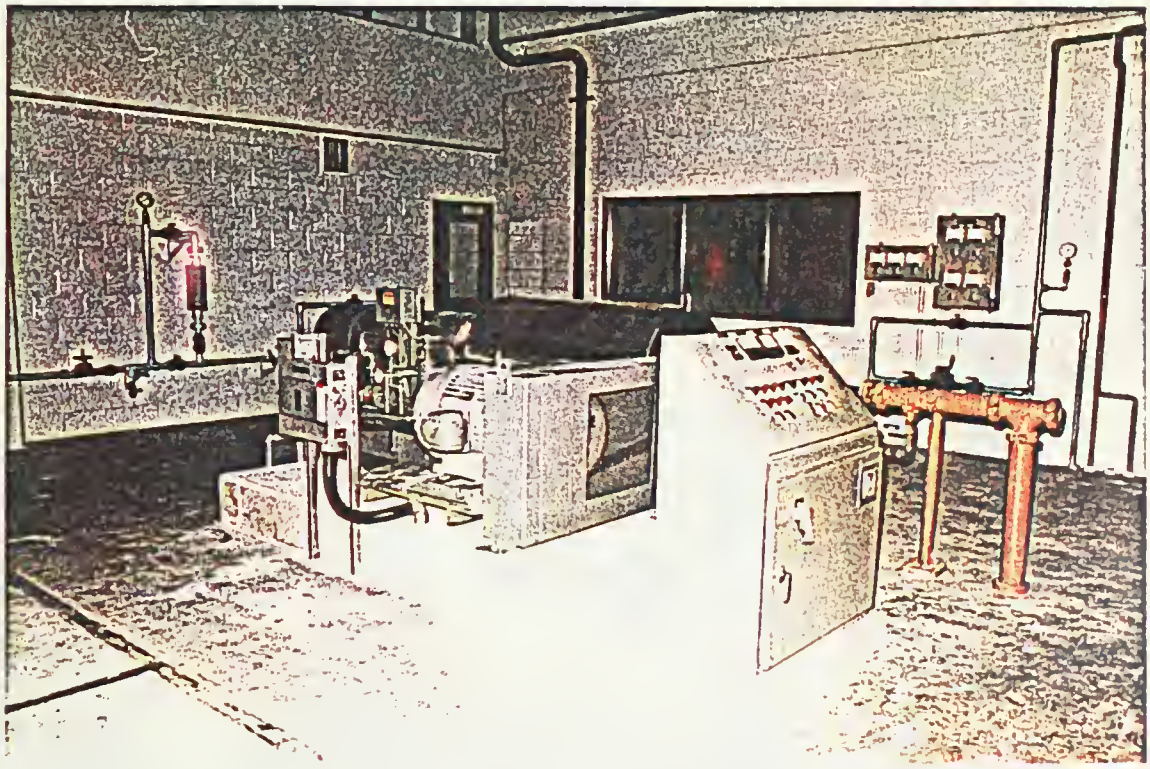
15. Parallel Plate Clarifier and Thickener



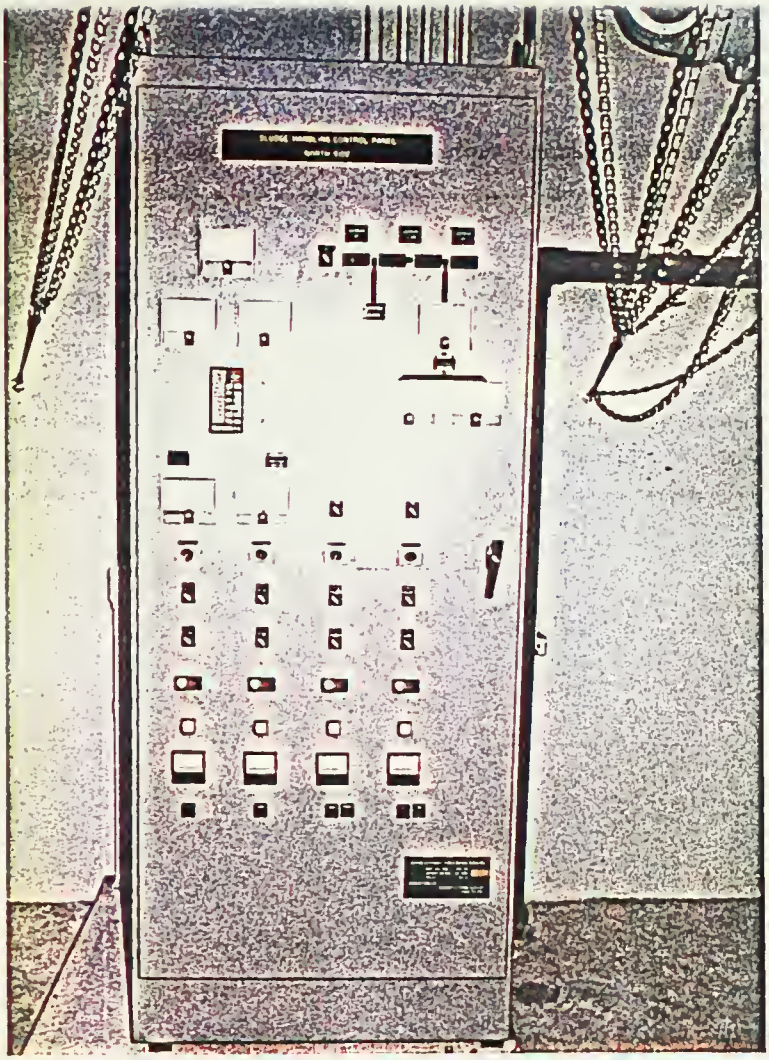
16. Water Treatment Polymer Room South - Coagulant Aid and Filter Aid Polymer Equipment



17. Sludge Pump Room - 1 Recirculation Pump and 2 Sludge Waste Pumps

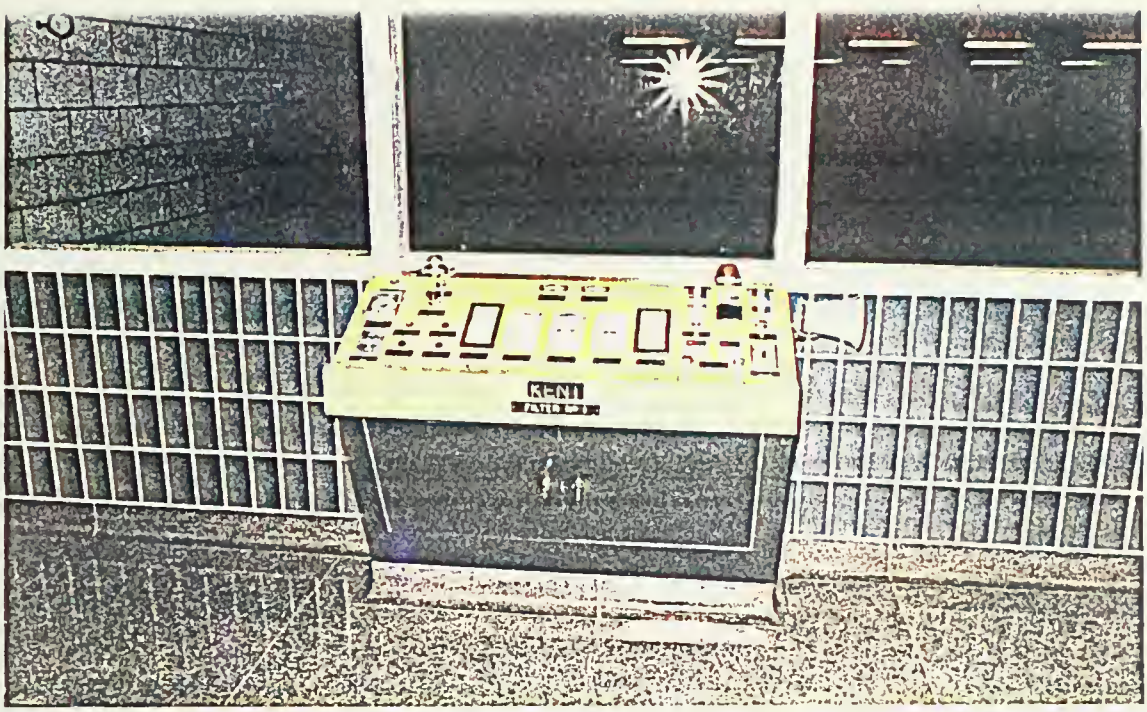


18. Centrifuge Room - Sludge Dewatering Solid Bowl Centrifuge and Controls



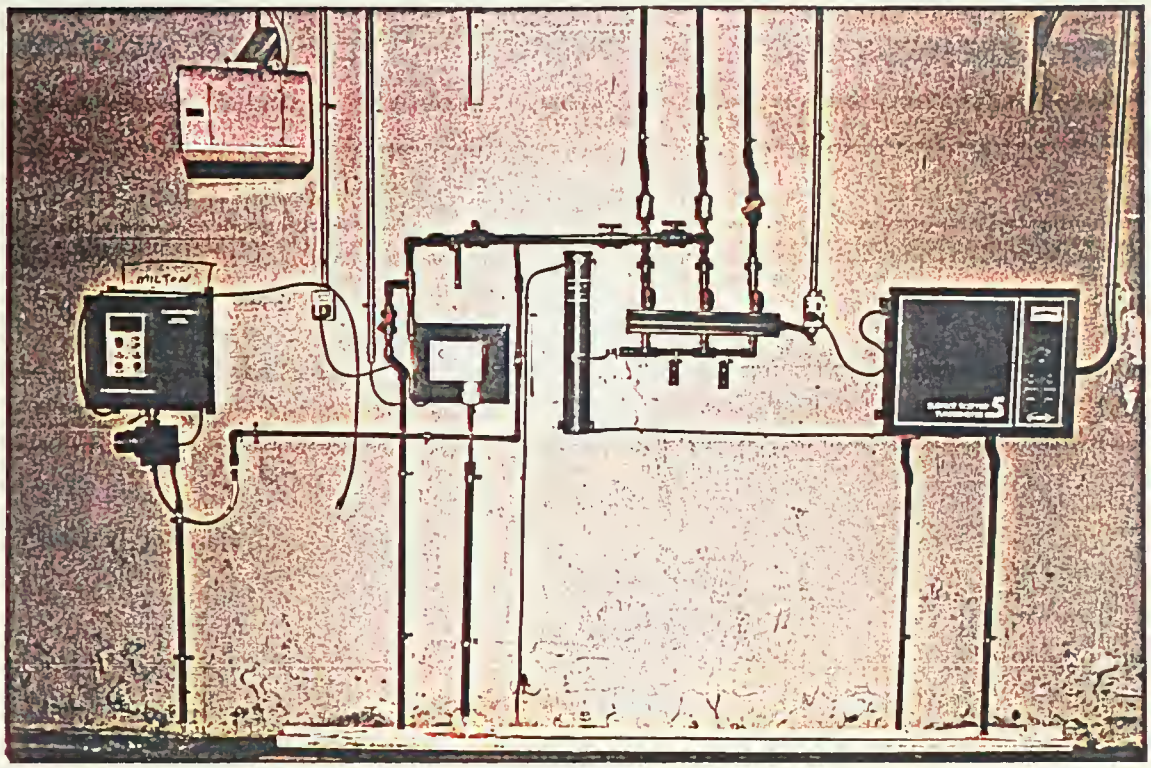
19. Sludge Handling Control Panel

20. Filter Operating Gallery



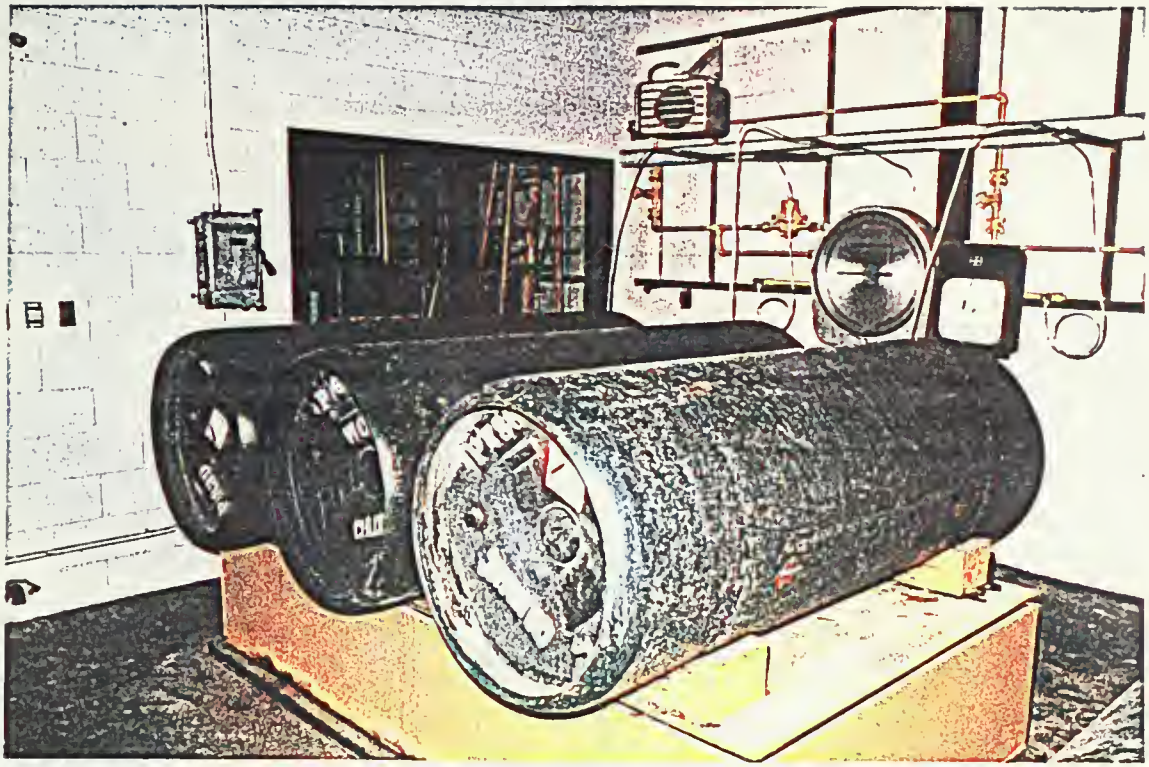
21. Filter Operating Gallery

22. Filter Pipe Gallery - Effluent Piping and Control Valve

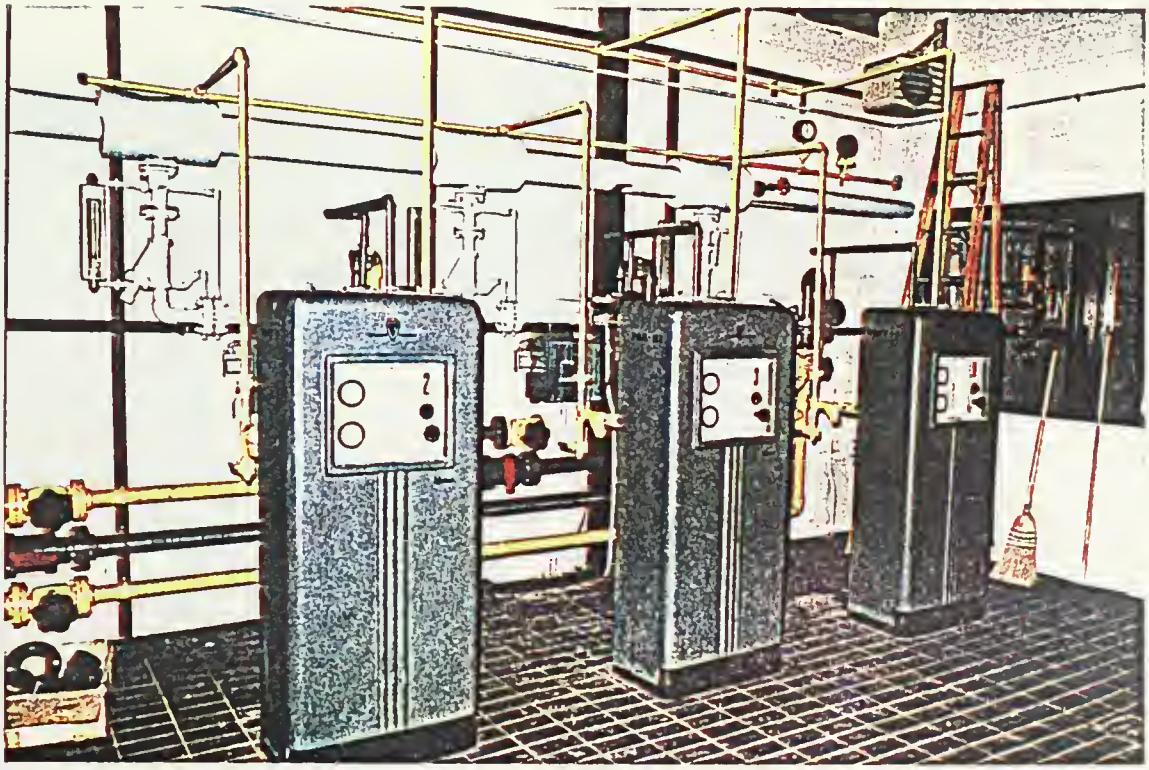


23. Main Pipe Gallery in Flocculation Bulding - Turbidity and Streaming Current Analyzers

24. Chlorine Building

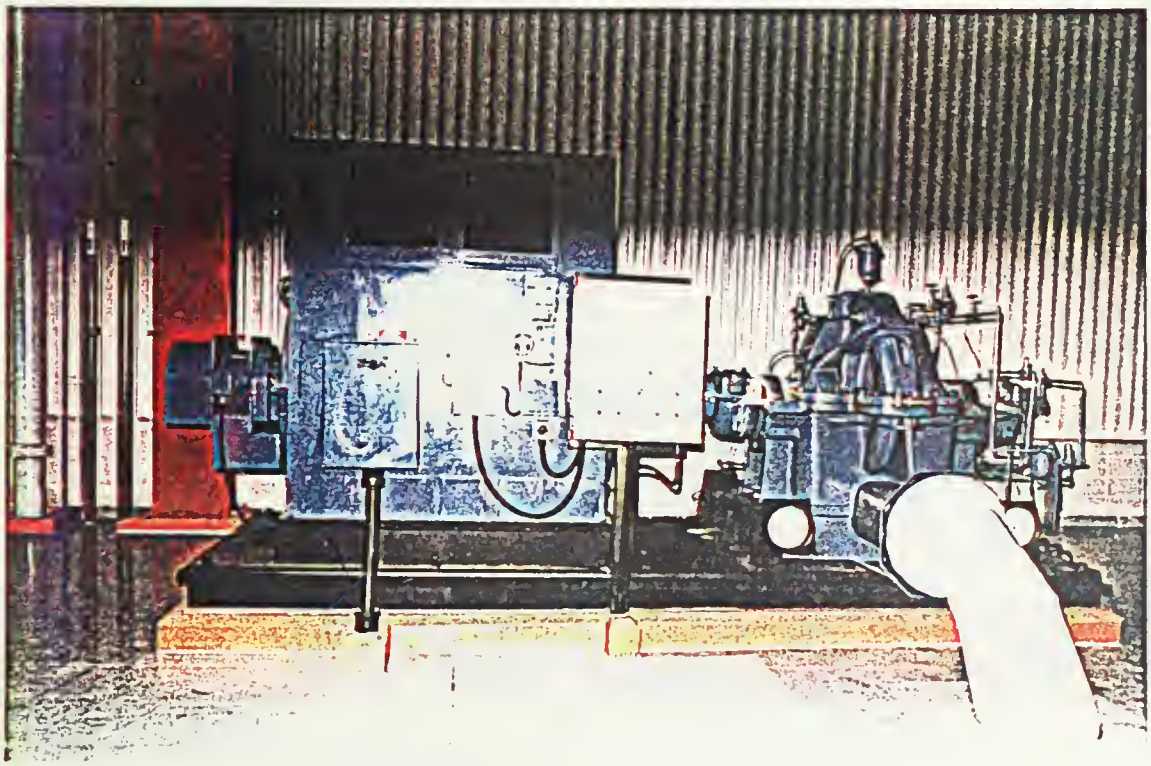


25. Chlorine Storage Room - 3 Ton Container Weigh Scale

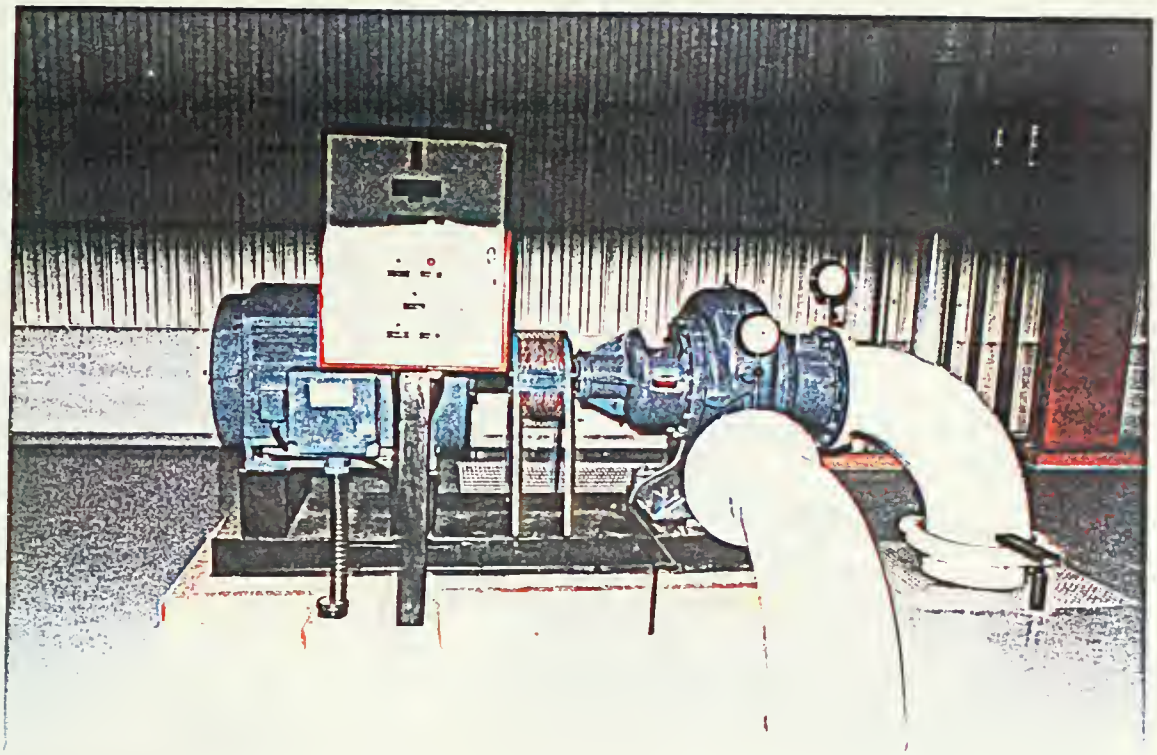


26. Chlorine Equipment Room - 1 Prechlorinator and 2 Postchlorinators

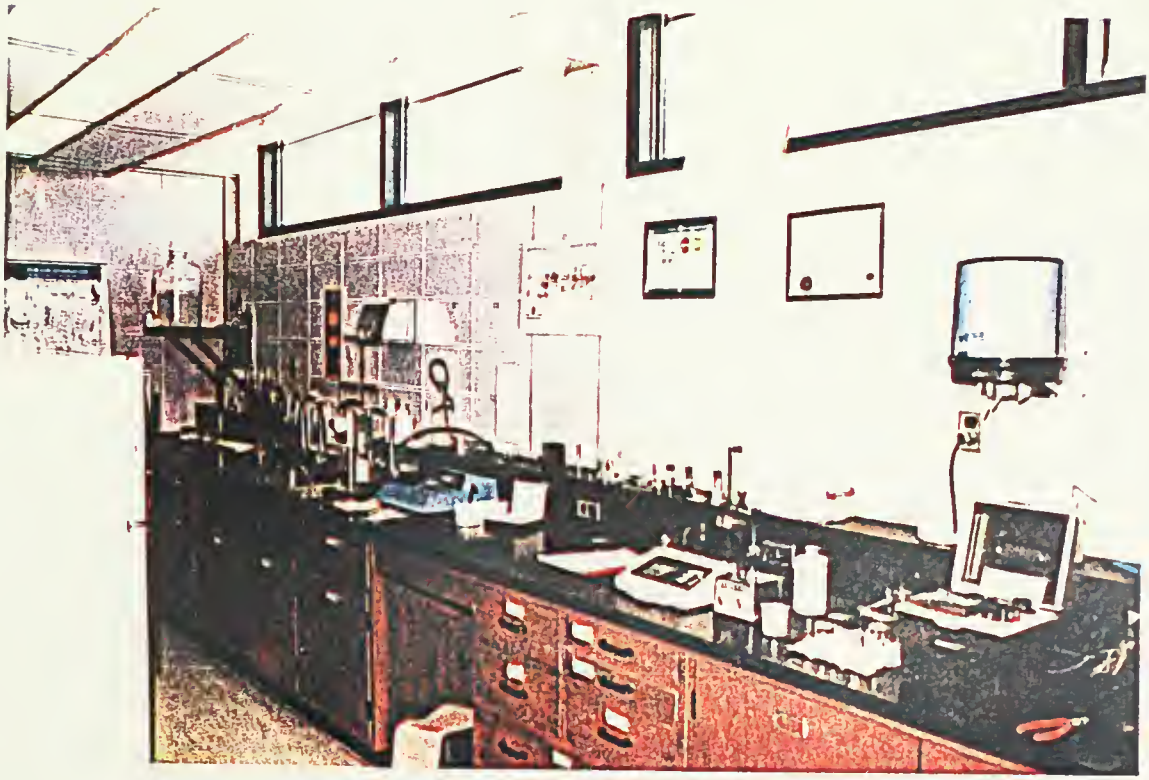
27. High Lift Pump Room Floor



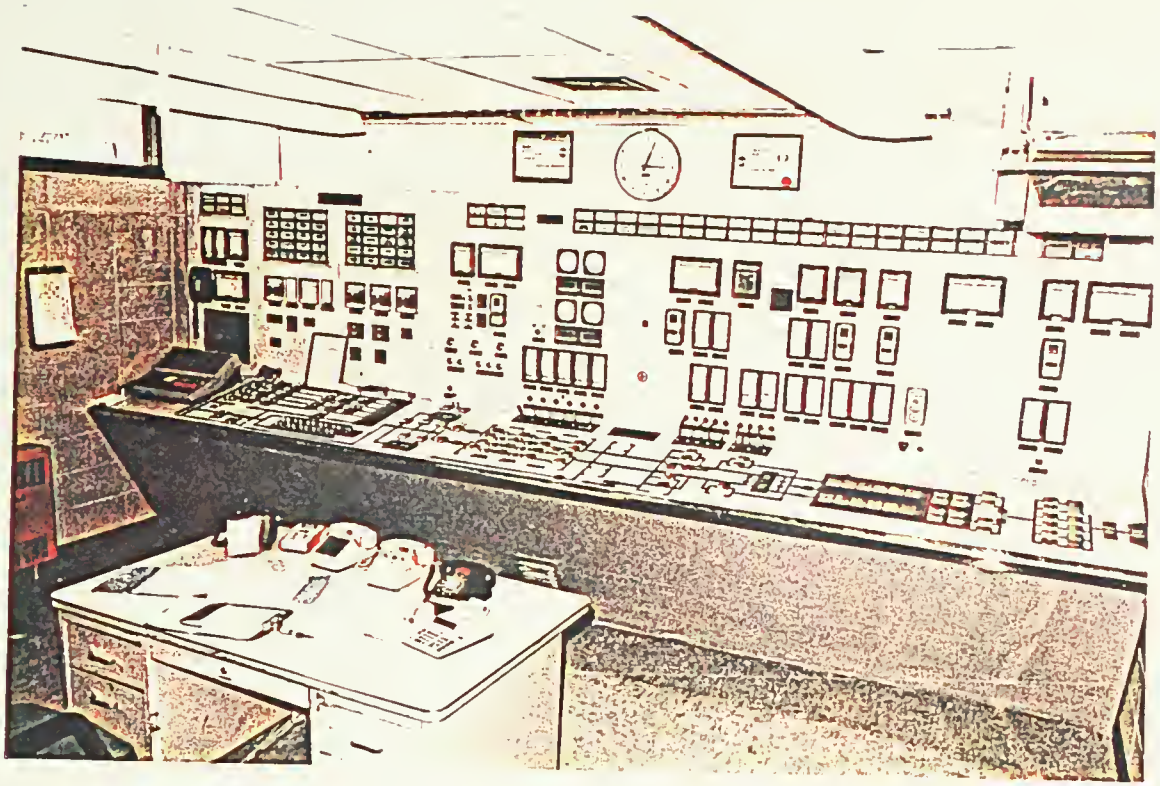
28. High Lift Pump



29. Filter Wash Water Pump



30. Laboratory



31. Control Room

SECTION D

PLANT OPERATION

D. PLANT OPERATION

D.1 GENERAL DESCRIPTION

a) General

The London (Lake Huron) Water Treatment Plant was originally designed and constructed as a direct filitration plant. Treatment processes for particulate removal consisted of flash mixing, flocculation, and dual-media filtration. In 1985 to 1986 the plant was expanded and upgraded. Sedimentation facilities were added to ensure the plant's capability to treat water at the design flow rate under all raw water quality conditions. In addition, facilities were added for the treatment and disposal of settled solids from the clarifiers.

Chemical treatment processes available at the plant consist of:

- a primary coagulant (alum) feed system for coagulation;
- polymer systems for use as 1) a coagulant aid, 2) a filter aid, and 3) a dewatering aid in centrifugation;
- disinfection facilities using chlorine gas for pre- and post-chlorination;
- pH adjustment facilities for the treated water using caustic soda,

The new facilities for sludge treatment provide for thickening of settled solids, dewatering of thickened sludge, and truck disposal of the dewatered sludge cake to a sanitary landfill.

b) Operation

Although the plant was equipped with an automatic process control system for pump and flow control units, as previously described in Section C.3, the plant is operated primarily on the basis of remote manual and local manual modes. Exceptions pertain to the low lift

pumps and the filters which are operated automatically most of the time. The automatic filter backwash program is also still functional but backwashing is manually initiated to allow low lift pumps to be switched to manual. In the auto mode low lift pumps would cycle off/on during a backwash due to the rapid drawdown of the Clear Well level.

Chemical feed systems are manually initiated using selector switches or pushbutton controls but are automatically paced proportional to flow.

Operating staff consists of the following:

- 1 Plant Superintendent
- 1 Assistant Plant Superintendent
- 11 Operators
- 7 Mechanical Maintenance Technicians
- 1 Electrician
- 1 Instrument Technician
- 1 Building Maintenance Man
- 1 Grounds Keeper
- 1 Secretary.

Water quality control analyses, described later in Section D.6, are performed by the operators in the Plant Laboratory. Additional tests are conducted to check the calibration of continuous on-line monitors.

The plant operates on the basis of 2-12 hour shifts per day, 7 days per week. Two operators are on duty during the day shift and one operator mans the night shift. Maintenance staff work an 8-hour day shift while office and supervisory staff observe a 7-hour day shift.

One operator staffs the Control Room while the second operator on the day shift monitors plant operations, carries out water quality tests, sets chemical feed rates, confirms the accuracy of on-line monitors, is in charge of receiving chemical deliveries, and backwashes filters.

Record keeping consists of maintaining the Daily Log Sheet and the Daily Lab Report. These two reports are combined monthly into the

Operating Report. In addition, plant staff prepare an additional monthly Utility Monitoring System Report and a yearly Plant Operation Summary.

D.2 FLOW CONTROL

a) Low Lift Pumps

Low lift pumps are normally controlled automatically from the Low Lift Area Central Control Panel based on:

- level in the Raw Water Conduits (before the filters); and

- the rate of filtration (as determined by a rising or falling water level in the Clear Well).

The first duty pump is manually selected. Other duty pumps will start and stop to maintain the water level in the conduit. The control range is set at 460 mm. The filter rate signal functions in addition to the level control and determines the number of pumps in service. At low level in the conduit and increasing filter rate, an additional duty pump will start whereas at high water level and decreasing filter rate an additional duty pump will stop to respond to the change in demand.

During backwashing operations of a filter, the low lift pumps are operated manually. This prevents cycling of the pumps as a result of rapid changes in the Clear Well level.

Pumps will lock out automatically based on low level in the pump well.

b) Pretreatment Units

Under normal operation flow through pretreatment units (rapid mix, flocculation and clarifier/thickener tanks) is not controlled. Shut-off gates exist whereby either one of the two Pretreatment Modules can be taken out of service or pretreatment can be by-passed entirely.

c) Filters

Filters are operated on the principle of constant rate filtration which means that the filter rate is not allowed to decrease in proportion to the increase in head loss during a filter run. Filter rate however can still be varied during operations to match the pumping rate demand on the Clear Well. Flow through the plant is divided equally by all on-line filters.

Filter rate control can be automatic or manual. In the manual mode filters run at constant rate controlled by a filter rate controller. The filter rate is set manually on the rate controller. A Venturi tube flow meter in the discharge pipe provides the flow rate for comparison to the set point. Deviations in flow rate are adjusted automatically from the rate controller by opening or closing of the rate control valve.

In the automatic mode the filter rate set point is automatically adjusted based on level in the Clear Well. The top 760 mm depth in the Clear Well is used for variable rate control. The remote filter flow rate setting signal is calculated by an Analogue Computing Device (on the Main Control Panel) and is equal to the rate of change of the proportional level band divided by the rate conversion coefficient. On high water level the filters shut down.

With the higher plant flow rates, experience has shown that the master filter rate control system is sensitive to rapid drawdown of the clear well level resulting in surges in filter rate and cycling of the low lift pumps. For these reasons filters are operated in manual mode during the backwash of a filter.

Washing of the filters is normally done automatically (but can be manual) from individual Filter Control Consoles. The backwash program must be initiated manually by the operator. An alarm will sound when a filter is ready for washing based on:

1) a filter having reached terminal head loss of 2.4 m; or

2) when the filter has reached a preset "time in service" (adjustable - 60 hours for direct filtration, 72 hours for conventional treatment).

At the end of the backwash cycle the filter is automatically returned to service by slowly opening the filter rate control valve which is equipped with a powered valve positioner (air operated pneumatic cylinder). A stepping drive relay in the filter rate controller will limit the rate of flow acceleration while the filter is being started up.

d) High Lift Pumps

Control of the treated water pumps and their respective discharge valves is remote manual from the Main Control Panel based on a water level measurement at the Arva Terminal Reservoir. With the operation of the Ausable Booster Pumping Station, booster pumps are controlled remote manual from the plant using the Arva Reservoir level measurement and the high lift pumps are then selected to match the pumping rate of the booster station. Alternatively, the high lift pumps could be controlled on the level of the Ausable Reservoir.

Emergency stop pushbuttons and pump lock-outs are available on local pump control panels. Pumps will trip out automatically based on low level in the Treated Water Suction Channel.

Service water pumps which also supply water to Grand Bend, are manually controlled from the Main Control Panel. An automatic mode is available whereby the base duty pump is operated manually and other pumps are sequenced according to the flow demand.

D.3 DISINFECTION PRACTICES

Pre- and post-chlorination for disinfection is practiced at the plant. The pre-chlorine dosage is applied in the surge well of the Low Lift Pumping Station.

The pre-chlorinator dosage is set manually and paced on summated raw water flow. Dosage is selected in order to maintain a free chlorine residual of about 0.5 mg/L after the filters. Pre-chlorination is discontinued during June, July and August due to the development of potential taste and odours from elevated levels of algae in the source water. Whether this has an impact on the rate of filter clogging due to live algae carry-over has not been established.

The post-chlorinators are operated similarly to the pre-chlorinator except that the machines are paced to maintain constant dosage on respective summated north and south filter bank flows. The chlorine diffusers are located at the outlet of the Filtered Water Conduits, Conduit No. 1 and No. 2. Dosage is set to maintain a total chlorine residual of 0.9 to 1.1 mg/L in the treated water pumped to the London pipeline and local distribution. An auto-chlorine analyser was used to continuously monitor the chlorine residual of the final effluent. The unit is currently out of operation but will be replaced in 1988.

D.4 OPERATION OF SPECIFIC COMPONENTS

D.4.1 Intake

No special operating procedures apply to the intake, and no serious operational problems have been encountered. During the spring when the ice breaks up some frazil ice is carried through to the surge well of the pumping station. Shut-off gates are available to isolate the intake from the Low Lift Pumping Station.

Facilities for backflushing of the intake are available but have never been used.

D.4.2 Screening

Screens are in good condition. They are self-cleaning when in operation. Wastes are discharged to the drain and back to the lake via the 1060 mm dia. outfall.

D.4.3 Low Lift Pumps

Basically, low lift pumps are operated to match treated water flow. This is achieved in the manual or automatic mode by maintaining a controlled water level in the Raw Water Conduits and in the Clear Well.

D.4.4 Rapid Mixing

Rapid mixers are manually operated at constant speed to continuously blend chemicals with the raw water. Start/Stop pushbutton loading stations are available at the motors.

D.4.5 Flocculation

Mechanical flocculators of the walking beam type are equipped with variable speed drives. These units are manually operated from local control panels. Motors are equipped with manually adjustable variable speed fluid drives that will permit a wide selection of energy gradients from 23 s^{-1} to 65 s^{-1}. The current settings for all flocculators are similar and provide a mean velocity gradient of 23 s^{-1} in each well.

D.4.6 Sedimentation

Settling clarifier/thickeners follow rapid mixing and flocculation tanks. Flow through the units is by gravity due to hydraulic head established by the low lift pumps.

The clarifier/thickener rotating assembly consists of a picket-fence thickener and sludge scraper mechanism for mechanical sludge removal. the mechanism is driven by a single motor drive which is operated manually from a local control panel.

Pumps are available for sludge recycle to the rapid mixers and for sludge wasting to dewatering centrifuges prior to off-site disposal.

Sludge recycle pumps can be operated manually or automatically from local or the remote Sludge Handling Control Panels (North and South). In the manual mode the pump speed is manually adjusted by speed adjust switch to the desired recycle flow rate. In the automatic mode, the pump speed is paced by either the north or south raw water flow signal via a process controller. The speed control signal is conditioned by the discharge flow signal from the sludge recycle magnetic flow meter. Turbidity of the flocculated water is used as a guide in selecting the solids recycle rate.

Sludge waste pumps are operated manually from the respective Sludge Handling Control Panel or remotely from the Centrifuge Control Panel. The discharge rate can be controlled by adjusting the speed of the pump on the speed controller.

D.4.7 Filters

Filters are operated on the basis of constant rate filtration, control normally is automatic from the Master Rate Controller based on changes of Clear Well level over a designated operating band of 760 mm. At the maximum level the filter rate control valve will be closed while at the minimum level of the proportional band, the valve will be open to discharge 1/12 of the designated design flow rate of the plant. At any intermediate level, the level signal is conditioned by a PID controller to produce the master filter rate-setting signal.

In the manual mode of filter operation, the set point flow rate will be manually established by the operator. Individual rate controllers respond by throttling of the rate control valves to maintain constant flow. The degree of throttling will depend upon the head loss build-up in each filter.

During filter backwashing operations, filters are operated in the manual mode. This eliminates surges in filter rate and cycling of low lift pumps due to rapid drawdown of the Clear Well level. Filters are returned to the auto mode after the Clear Well level is back to normal.

Filters are monitored for flow, head loss, length of time in service, and effluent turbidity. The need for backwashing a filter is indicated on the basis of high head loss or the length of filter run. A head loss of 2.4 m will sound an alarm alerting the operator to initiate the backwash. Similarly, an alarm will sound at the end of a run which for direct filtration was set at 60 hours while for conventional treatment it is established at 72 hours. Once initiated, filter backwashing will proceed automatically in accordance with the program of the analogue controller. Backwashing is done first at low rate, then at high rate by controlling the operation of the three backwash pumps. Surface agitators come on-line at the beginning of the wash cycle and run for about 3 minutes. Agitators are controlled automatically by opening/closing of a motorized inlet valve. The duration of a filter wash is about 15 minutes. At the end of the wash cycle, the filter is automatically returned to service. Filter start-up is gradual by opening the rate control valve at a controlled ramped rate. This minimizes hydraulic surges in the filter and reduces the initial high turbidity normally experienced at start-up.

Filters can be backwashed manually from individual Filter Control Consoles.

D.4.8 Clear Well

Filtered water from the Filtered Water Conduits, No. 1 and No. 2, discharges by gravity to each cell of the Clear Well (North and South). Flow enters the Clear Well through 900 mm x 1220 mm sluice gates, one for each cell, traverses through the two chambers in each cell in plug-flow fashion and exits through 1830 mm x 1220 mm sluice gates to the Treated Water Suction Conduit. Outlet gates are set at the bottom of the Clear Well and hence do not control the water level in the well.

Chlorine and caustic soda solution diffusers are located in the Filtered Water Conduits ahead of the Clear Well inlet gates.

With the automatic filter rate control system in operation, the Clear Well water level is generally at its maximum resulting in a chlorine

contact time during post-chlorination of 28 minutes at the design flow rate. Up to 7 minutes of additional maximum contact time is available in the Treated Water Suction Conduit before local distribution to Grand Bend. Considerably longer detention times are available for flow distribution to the City of London. The available storage capacity includes about 59,000 m^3 in the pipeline, 18,000 m^3 in the Ausable Reservoir, and 55,000 m^3 in the Arva Terminal Reservoir, or a total of 132,000 m^3. For this capacity the detention time at the design flow rate is 9.4 hours. In view of this long travel time, re-chlorination facilities are available at the Arva Reservoir.

D.4.9 Waste Water Treatment

Excess sludge from the clarifier/thickeners is pumped to one of two centrifuges for dewatering. The thickener underflow normally varies from 4 to 12% dry solids by weight which after centrifugation attains a consistency typically in the range 0 of 20 to 30%; maximum concentrations of 40% dry solids by weight have been achieved. An anionic polymer solution may be applied to the sludge feed at an average rate of 2 kg/tonne dry solids to aid the dewatering process. With a highly concentrated sludge feed stream, dilution water is added to improve the flow of solids through the unit.

Pumps are controlled as previously described. Centrifuges are operated manually from individual local control panels.

The semi-wet sludge cake produced by the centrifuge is trucked to a sanitary landfill; whereas the centrate is discharged to the plant drain and returned to the lake. At present, sludge dewatering and disposal operations are intermittent and carried out only on weekdays during the day.

Filter backwash water which contains only a small percentage of the total waste solids generated at the plant, is discharged directly to the plant drain.

D.5 CHEMICALS

D.5.1 Control of Chemical Dosages

a) Prime Coagulant

Following start-up of the plant expansion in November 1986, liquid alum has been used as the primary coagulant without the assistance of any polymer aids.

Before the expansion, in 1986 and 1985 alum and ferric chloride were used independently or, at times, together. In addition, polyaluminum chloride (PACl) was used on an experimental basis for various periods during four months in 1985 and two months in 1986. The coagulant was dosed alone, in combination with alum or ferric chloride, or with both coagulants at the same time.

With the direct filtration process, a filter aid polymer was also applied at various times during 1985 and 1986. The polymer was used intermittently in 1985, essentially from January to May and again in December. In 1986 the filter aid was added during June and July, and September and October.

The ferric chloride and PACl were used at full commercial strength but the alum solution was diluted by 50 per cent in order to prevent alum from crystallizing in piping and feed tanks. Dilution water was added to the metered flow downstream of the feeder.

The applied alum dosage for direct filtration was selected on the basis of the quality of the raw and filtered water. Relative to raw water turbidity the dosage guide used up to November 1986 when operation of the conventional treatment mode commenced was as follows:

Raw Water Turbidity (mg/L)	Alum Dosage (mg/L)
<5	8
5 - 10	9
10 - 20	12
20 - 40	15
40 - 60	17
60 - 100	20
100- 125	25
125 - 150	30
150 - 175	35
175 - 200	40

With increasing filter effluent turbidity, the dosage was increased to the next higher value in order to maintain a filter effluent turbidity of less than 0.3 FTU.

With the onset of conventional treatment, jar tests are no longer performed. Rather, a trial coagulant dosage is selected based on the effluent turbidity in settled water, and reduced in increments until the filter effluent quality starts to deteriorate. The critical dosage is then accepted as the optimum and used for setting of the Streaming Current Detector (SCD).

The alum dosage applied was calculated by plant staff using the daily consumption based on Rotodip revolution counter readings and daily raw water flow.

The calculated dosage is checked regularly by comparing calculated consumption with the loss of volume in the solution storage tank.

PACl dosages were determined in the same manner as the alum dosages described above. The ferric chloride consumption was calculated daily based on the rate settings of the pumps and dosages were calculated based on the daily volume of raw water treated.

b) Polymer Aid - Before Plant Expansion

Before the plant expansion a polymer filter aid was applied when necessary to the flocculated water before the filters.

For the first three months in 1985 Separan NP10, a nonionic polymer, was used. The dosage applied ranged from 0.01 to 0.08 mg/L and the average was in the order of 0.04 to 0.05 mg/L. For the remainder of 1985 and until October 1986, Drew 6306A nonionic polymer was used from time-to-time at a dosage ranging from 0.001 to 0.014 mg/L with an average of 0.006 to 0.011 mg/L. There were no apparent reasons why the minimum dosage was so low.

Dosage selection was based on performance of the filters, the objectives being 1) to maintain filter effluent quality and 2) to achieve terminal head loss or end of filter run based on time in service without incurring filter turbidity breakthrough.

The applied dosage was calculated daily in the same manner as the ferric chloride dosage. Calculated consumption of polymer was compared with the daily loss in volume in the polymer storage tank.

c) Polymer Aid - After Plant Expansion

The original polymer filter aid system was replaced by two new polymer feed systems for dosing of:

1) a cationic polymer as a coagulant aid, and
2) a nonionic polymer as a filter aid.

The two systems can be used individually or together to improve sedimentation and/or filter performance.

With the conventional treatment, the plant has performed exceptionally well and no polymer aids have been used since the clarifiers were placed in service.

Polymer systems are equipped with sonic level indicating transmitters on storage tanks and positive displacement flow meters on metering pump discharge lines. It will therefore be possible to establish an accurate record of daily polymer consumption as well as the applied daily dosages.

A third polymer aid system has been provided for dosing of an anionic polyelectrolyte as a dewatering aid. The system has not been used yet but similar instrumentation is available as for the coagulant aid and filter aid feed systems which will allow for an accurate calculation of the daily dose.

The polymer dosage will be selected on the basis of the performance of the centrifuge. From experience, facilities were designed for an average rate of polymer consumption of 2 kg/tonne of dry solids.

d) Caustic Soda

Caustic soda dosing facilities for pH correction were installed under the recent plant expansion. This system has not been used yet but is capable of providing pH correction of the treated water by as much as one to two pH units.

Caustic soda can be applied at the inlet to the Clear Well to counter the alkalinity demand of the chlorine added in post-chlorination.

Daily dosages will be calculated from recorded consumption of caustic soda and the daily measured amount of water treated.

e) Chlorine

As reported previously in Section D.3, chlorine gas in solution form is used for disinfection and taste and odour control. The raw water is pre-chlorinated, except for June, July and August as described in Section D.3 above and the filtered water is post-chlorinated.

The pre-chlorine dosage is set manually at 0.7 to 0.8 mg/L to maintain a free chlorine residual of about 0.5 mg/L after the filters.

The post-chlorine dosage is set manually at 0.6 to 0.7 mg/L to maintain a total chlorine residual of 0.9 to 1.1 mg/L in the treated water delivered from the plant.

When pre-chlorine is not applied the post-chlorine dosage is raised to about 1.3 mg/L in order to maintain a similar total chlorine residual in the treated water as for the pre- and post-chlorination practice.

Chlorine dosages are calculated using the daily chlorine consumption for pre- and post-chlorination obtained from the chlorinator feed rate settings and the daily water treated. Total daily calculated chlorine consumption is checked against the actual chlorine weight consumed as indicated by the chlorine scale loss-of-weight indicator.

D.6 SAMPLING AND DATA COLLECTION

D.6.1 Plant Records

The following records are kept by the operators for monitoring plant operations:

1) Daily Log
2) Monthly Operating Report
3) Monthly Utility Monitoring System Report
4) Yearly Plant Operation Summary.

An example of the Daily Log is included in Appendix A of this report. Information, documented for the three-year operating period for this plant optimization study, is presented in Appendix D, Tables 1.0 to 6.0 inclusive.

D.6.2 Process and Quality Control

The plant operator is responsible for maintaining the Daily Log Sheet and the Daily Lab Report. Data are recorded three times per shift or six times per day and include information of flows, chemical treatment and quality control testing. At the end of the day the information is summarized and daily maximum, minimum and average values are recorded. Specific entries of the above forms include the following;

a) Flows

- raw water flow to pretreatment basins (summated flow signal for two individual flow meters);
- summated filtered water flow (based on individual filter flow meters);
- backwash water flow;
- total service water flow and amount pumped to distribution;
- summated plant output - total flow pumped to the London pipeline.

b) Chemical Treatment

- liquid alum or PACl . consumption in kg/d, based on totalizer readings for the Rotodip feeder transmissions

- liquid ferric chloride and polymer filter aid (before expansion)	. consumption in kg/d, based on metering pump feed rate.
- polymer aid systems meter and caustic soda	. consumption in kg/d, based on flow totalizer and loss-of-level in storage tank
- chlorine	. consumption in kg/d for pre-chlorination and post-chlorination, based on feed rate settings . total consumption is confirmed from loss-of-weight scale in chlorine storage room.

c) Quality Control Testing

The following analyses are carried out at the water treatment plant:

- turbidity	. 6 times per day using a Hach Ratio Turbidimeter for raw, pre-filtered water and plant effluent . on-line monitoring plus recording every 1/2-hour for raw, coagulated, settled, filtered and plant output water
- temperature	. raw water, 6 times per day
- pH	. raw and treated water, 6 times per day
- chlorine residual	· filter effluent free and plant output total, 6 times per day, using a W & T Titrator

- aluminum and iron . 1 time per day using a Hach DR-A-4454 Colorimeter on plant output.

Samples for above analyses are obtained in the lab from the appropriate sample tap.

D.6.3 Water Quality Examination

Water quality analyses for various chemical, biological and bacteriological parameters are carried out routinely at the Ministry of the Environment laboratories. Parameters that have been analyzed for and the frequency of the analyses are as follows:

- bacteriological analyses . at MOE lab in London, raw and treated water; 1 sample per day every Monday/ Tuesday and Thursday/Friday
- algae . at MOE lab in Toronto, raw water: weekly samples analyzed as a monthly composite
- general chemistry . once per week at MOE lab in Toronto
- organic parameters . only commenced as part of the MOE-DWSP, once per month at MOE lab in Toronto.

D.6.4 Laboratory Equipment

Equipment available at the plant laboratory includes the following:

- 1 - Hach Ratio Turbidimeter
- 1 - Hach DR-A-4454 Colorimeter
- 1 - Beckman 040 pH Meter, digital
- 1 - W & T Chlorine Residual Titrator
- 1 - Titration Burette Stand
- 1 - Phipps & Bird Jar Test Apparatus
- 1 - Olympus Microscope, ECBi, 4X to 100X magnification.

D.7 PROCESS AUTOMATION

Reference is made to Section C.6 for a description of the available automated equipment. The analogue supervisory monitoring and control system as originally installed did permit complete automatic operation of the plant except for filter backwashing which had to be manually initiated. However, in view of the age of the system, and the unavailability of replacement parts, several of the automatic components are no longer functioning. Also, with increasing system demand, operating problems were encountered with the automatic low lift pump control and master filter rate setting algorithms. For these reasons the plant is currently operated in a semi-automatic mode from local area control panels and the Main Control Panel. The high lift pumps and Ausable Booster Station pumps can be operated automatically but are operated in the remote/manual mode for energy conservation reasons.

Reference is made to previous sections of this report for a more detail discussion of the operation of individual processing units.

D.8 DAILY OPERATOR DUTIES

The plant superintendent is responsible for the treatment process and all activities that take place at the plant. He holds a supervisory and staff management position and deals with matters relating to the public. The assistant plant superintendent is responsible for plant maintenance.

Plant operators are responsible for the day-to-day running of the plant including the following major activities:

- keep records of process operations, chemical treatment and quality control testing;

- check operation of all equipment and respond to problems when they arise;

- initiate filter backwashing and observe operations;
- respond to and record treatment upsets, equipment outages, unusual events such as cases of vandalism;
- carry out water quality control tests and collect water samples for analysis by outside laboratory;
- confirm accuracy of on-line monitors - turbidity, chlorine residuals;
- confirm flow rate accuracy of liquid chemical metering equipment and chlorinators;
- receive chemical deliveries and ensure adequacy of supplies;
- exercise mechanical standby equipment such as chemical feeders;
- respond to alarm conditions.

In addition to the physical tasks listed above, operators must stay in constant communication with the plant superintendent and the plant maintenance personnel.

SECTION E

PLANT PERFORMANCE

SECTION E - PLANT PERFORMANCE

E.1 GENERAL OVERVIEW

Plant operations and performance of the London (Lake Huron) Water Treatment Plant were discussed with the Plant Superintendent during site visits that were undertaken in November 1987 and in February 1988. It was established that the plant is operated in a semi-automatic mode from local area control panels and the Main Control Panel as summarized below:

- The low lift pumps are normally operated automatically from the Central Control Panel based on the level of the Raw Water Conduit and the rate of filtration. Control is switched to manual during filter backwashing operations so that pump cycling will not occur due to rapid changes in filter rate.

- Filters are operated similarly to the low lift pumps. The normal operation is automatic at variable filter rate except during backwashing, when the manual mode is preferred. In the automatic mode the filter rate is continuously adjusted (from zero to the maximum design filter rate of 27,300 m^3/d per filter) based on the level of the proportional level control band in the clear well. To prevent sudden changes in filter rate, therefore, the filters are manually operated at constant rate during backwashing operations until the clear well level returns to normal.

- Filter backwashing also is automatic following manual initiation of the backwash cycle. The need for backwashing will be indicated by an alarm for either 1) high head loss, or 2) end of filter run based on time in service, whichever comes first.

- Chemical feed systems are operated in a semi-automatic mode by quantitatively pacing preset dosages relative to flow.

- At present, with the Ausable Booster Pumping Station in operation, high lift pumps are selected remote/manually from the Main Control

Panel to match the pumping rate of the booster station. The booster pumps are controlled remote/manually from the plant based on the level in the Arva Terminal Reservoir. The Arva reservoir level will also serve to select high lift pumps when the booster pumping station is off-line.

The raw water is generally of good quality with the exception of high turbidities that occur during storm events and summer algae blooms.

Treated water quality has consistently met the objectives of the Ontario Drinking Water Objectives of 1983. Filter effluent turbidities during 1985 to 1987 were well below the 1.0 NTU objective and averaged 0.14 FTU during 1987 and November/December 1986 with conventional treatment. With direct filtration, the average turbidity of the treated water was 0.20 FTU for the remainder of 1986, and 0.25 FTU for 1985.

With regard to the bacteriological quality of the treated water for 1987 to 1985, Table 6.0 attests to the excellent record that has been achieved. All samples tested for total coliform bacteria were negative and only two samples of the entire 3-year record tested positive.

Algae in the raw water caused considerable problems with the operation of the direct filtration process. At high algae levels short filter runs were encountered, and the production capacity of the plant was limited to less than one-half its design capacity. Also, as a result of chlorination, the raw water algae would give rise to objectionable tastes and odours. Both of these problems have been eliminated, the first by the addition of sedimentation facilities to the process in 1986, and the second by not prechlorinating the raw water when the algae population is high. Suspension of prechlorination during the summer had no adverse effect on the bacteriological quality of the plant output.

Another problem that might be attributed to algae in Lake Huron water relates to the high summer pH levels. Raw water pH is important to the

treatment process and affects the efficiency of coagulation and chlorination, as well as the saturation level of dissolved aluminum. The high raw water pHs (above 8.5) give rise to potentially high levels of aluminum residuals in the treated water which, following postchlorination, lead to post-precipitation of aluminum floc. With the recent plant expansion, the problem of post-precipitation of aluminum floc has been addressed by the provision of caustic soda dosing facilities.

Table 7.0 in Appendix D serves to present an exceedance summary of measured parameters versus Ontario Drinking Water Objectives. As is evident from the table, none of the process parameters monitored during the study period exceeded the Ontario Drinking Water Objectives.

E.2 TURBIDITY

E.2.1 Evaluation of Particulate Removal Efficiency

a) Raw Water Quality

Operating records for particulate removal at the Lake Huron Water Supply System are presented in Tables 2.0 and 2.1 of Appendix D. Table 2.0 presents a monthly summary of the average, maximum and minimum raw and treated water turbidity values for 1985 to 1987. In addition, corresponding values are tabulated for i) primary coagulant, ii) filter aid' iii) aluminum and iron raw water residuals, iv) raw and treated water pH, and v) raw water temperature. Daily values for the same parameters are presented in Table 2.1 for January, April, July, and October for each of 1985 to 1987.

At the Lake Huron plant, particulate removal from the source water has been achieved by sedimentation and filtration since October 1986. Prior to the installation of clarification and sludge thickening equipment, direct filtration was practiced. Processes are made effective by the addition of alum in the rapid mix tank and by series flocculation in four cells of the coagulated water prior to sedimentation. The objective is to produce the highest achievable water clarity in the finished water, with the least amount of coagulant(s) addition under any of the occurring raw water turbidity conditions.

Raw water is drawn through an intake crib that is 2530 m offshore and submerged by about 8.8 m of water. At this location, a generally good but variable raw water quality exists throughout the year. This will be evident from the summary of raw water characteristics presented in Table E.1. The average monthly turbidity levels for 1987 varied from 2.0 to 2530 FTU and the yearly average value was 11.6 FTU. Graphs for the monthly variations in turbidity, daily maximums and average values are shown in Figure E.1 for the three-year period of record. Increased levels of turbidity are experienced during spring storms and in the fall and winter for durations ranging from a few days to a couple of weeks. Monthly daily maximum values ranged from 1.2 to 139.6 FTU.

In Figure E.2 turbidity frequency curves are presented for monthly maximum and average values. The curves illustrate the per cent of the time a given value of turbidity within the data range was exceeded during the three-year period of record. From the graphs it will be noted that average monthly turbidity is less than 20 FTU 90% of the time and less than 10 FTU 67% of the time. Daily maximum monthly turbidities are less than 70 FTU 90% of the time and less than 35 FTU 68% of the time.

An analysis of the durations of higher turbidity events was carried out. Tables E.2, E.3, and E.4 summarize periods with above average turbidity levels for 1987, 1986, and 1985 respectively. In reference to the data presented, it will be evident that the worst period occurred during early October 1986, when the daily average raw water turbidity reached 139.6 FTU, and the turbidity remained over 60 FTU for four consecutive days.

During the study period, maximum daily levels of turbidity lasted for only a day or two, but higher than average levels of turbidity persisted for about fifteen consecutive days. During these periods with higher than average levels of raw water turbidity, a slight decrease in the performance of the filters occurred during the direct filtration process. This is discussed in greater detail in the following section. The impact of higher raw water turbidity, however, was not as severe as it might have been since the plant flow rate was less than one-half its design capacity. For example, peak water

TABLE E.1

LAKE HURON RAW WATER CHARACTERISTICS IN 1987

(At the London (Lake Huron) W.T.P. Intake)

Month 1987	Average Turbidity (NTU)	Algae Count ASU/mL (1)	pH Units	Average Temp. °C	MPN Results For Total Coliform No. Of Results In Range From 6 - 100/ 100 mL (1) (2)
January	8.6	297	7.94	4	18
February	20.5	63	8.05	4	16
March	21.7	296	8.16	4	17
April	14.1		8.27	8	18
May	5.4	1999	8.47	12	18
June	2.0	1005	8.73	15	16
July	3.1	452	8.71	21	18
August	9.4	742	8.70	20	18
September	7.2	613	8.41	19	17
October	11.7	1023	8.06	14	18
November	14.9	1320	7.94	9	17
December	20.9	917	8.08	5	18

(1) Algae and coliform results are for 1985.

(2) All MPN test results were within the range indicated.

TABLE E.2

HIGH RAW WATER TURBIDITY EVENTS

1987

Date	TURBIDITY FTU	Date	TURBIDITY FTU	Date	TURBIDITY FTU
Jan 22	7.8	Mar 30	7.6	Nov 04	1.9
Jan 23	31.2	Mar 31	37.8	Nov 05	20.5
Jan 24	26.5	Apr 01	30.5	Nov 06	70.8
Jan 25	15.1	Apr 02	25.2	Nov 07	16.0
Jan 26	6.1	Apr 03	60.0	Nov 08	3.7
		Apr 04	49.8		
Feb 07	9.0	Apr 05	43.0	Nov 19	6.7
Feb 08	9.6	Apr 06	37.7	Nov 20	12.5
Feb 09	107.8	Apr 07	22.1	Nov 21	65.7
Feb 10	50.1	Apr 08	14.7	Nov 22	40.3
Feb 11	40.3	Apr 09	7.5	Nov 23	18.1
Feb 12	31.6			Nov 24	32.8
Feb 13	24.3	Aug 21	2.8	Nov 25	22.7
Feb 14	26.0	Aug 22	16.6	Nov 26	24.3
Feb 15	21.8	Aug 23	47.3	Nov 27	14.1
Feb 16	16.0	Aug 24	32.7		
		Aug 25	49.0	Dec 01	12.7
Mar 01	7.2	Aug 26	17.3	Dec 02	27.7
Mar 02	49.2	Aug 27	11.7	Dec 03	24.3
Mar 03	60.3	Aug 28	8.8	Dec 04	20.0
Mar 04	57.0			Dec 05	48.8
Mar 05	33.5	Sep 29	3.0	Dec 06	44.0
Mar 06	31.0	Sep 30	15.3	Dec 07	20.9
Mar 07	27.0	Oct 01	21.5	Dec 08	8.5
Mar 08	19.1	Oct 02	17.3		
Mar 09	58.6	Oct 03	47.0	Dec 15	8.3
Mar 10	46.7	Oct 04	17.1	Dec 16	26.7
Mar 11	19.1	Oct 05	11.4	Dec 17	68.8
Mar 12	15.0	Oct 06	10.9	Dec 18	49.0
				Dec 19	25.3
				Dec 20	12.9
				Dec 21	21.8
				Dec 22	10.6

TABLE E.3

HIGH RAW WATER TURBIDITY EVENTS

1986

Date	TURBIDITY FTU	Date	TURBIDITY FTU	Date	TURBIDITY FTU
Jan 25	5.4	Aug 23	4.0	Oct 05	9.6
Jan 26	5.8	Aug 24	41.3	Oct 06	139.6
Jan 27	17.7	Aug 25	11.8	Oct 07	81.6
Jan 28	10.4	Aug 26	9.0	Oct 08	64.3
Jan 29	6.6	Aug 27	24.8	Oct 09	73.0
Jan 30	4.9	Aug 28	17.9	Oct 10	28.3
		Aug 29	18.5	Oct 11	22.8
Mar 11	1.2	Aug 30	18.5	Oct 12	14.8
Mar 12	3.7	Aug 31	11.5	Oct 13	12.0
Mar 13	22.1			Oct 14	23.8
Mar 14	7.0	Sep 11	3.4	Oct 15	36.3
Mar 15	3.1	Sep 12	2.7	Oct 16	18.3
		Sep 13	18.2	Oct 17	13.0
Apr 08	3.0	Sep 14	42.7	Oct 18	15.9
Apr 09	10.8	Sep 15	73.5	Oct 19	12.3
Apr 10	16.5	Sep 16	18.8	Oct 20	10.8
Apr 11	22.5	Sep 17	14.3		
Apr 12	15.5	Sep 18	12.9	Nov 08	5.0
Apr 13	9.2	Sep 19	11.3	Nov 09	19.6
Apr 14	16.2	Sep 20	9.0	Nov 10	53.3
Apr 15	5.5	Sep 21	11.5	Nov 11	13.8
Apr 16	4.2	Sep 22	9.1	Nov 12	13.2
		Sep 23	12.3	Nov 13	21.9
May 01	5.2	Sep 24	7.5	Nov 14	15.7
May 02	30.5			Nov 15	6.2
May 03	26.2				
May 04	7.1				
May 05	11.7				
May 06	15.0				
May 07	18.3				
May 08	20.7				
May 09	15.0				
May 10	7.8				
May 11	6.9				

TABLE E.4

HIGH RAW WATER TURBIDITY EVENTS

1985

Date	Turbidity FTU	Date	Turbidity FTU
Jan 02	6.6	Jul 21	2.6
Jan 03	15.0	Jul 22	9.5
Jan 04	16.6	Jul 23	13.9
Jan 05	13.7	Jul 24	10.7
Jan 06	13.9	Jul 25	3.7
Jan 07	17.7		
Jan 08	23.7	Nov 13	8.2
Jan 09	21.8	Nov 14	21.1
Jan 10	7.8	Nov 15	13.3
		Nov 16	4.7
Jan 14	4.8		
Jan 15	20.5	Nov 27	6.3
Jan 16	19.7	Nov 28	11.9
Jan 17	13.7	Nov 29	20.5
Jan 18	9.0	Nov 30	14.3
		Dec 01	12.7
Feb 26	2.5	Dec 02	16.5
Feb 27	15.0	Dec 03	92.5
Feb 28	21.1	Dec 04	49.0
Mar 01	5.0	Dec 05	23.0
Mar 02	5.6	Dec 06	20.3
Mar 03	30.0	Dec 07	21.3
Mar 04	8.7	Dec 08	44.1
		Dec 09	21.9
Mar 11	11.5	Dec 10	13.2
Mar 12	25.8	Dec 11	9.8
Mar 13	21.8	Dec 12	11.8
Mar 14	14.8	Dec 13	16.5
Mar 15	37.0	Dec 14	43.0
Mar 16		Dec 15	20.7
Mar 17	24.5	Dec 16	12.9
Mar 18	16.6	Dec 17	27.6
Mar 19	14.2	Dec 18	11.7

WPOS - LAKE HURON WATER SUPPLY SYSTEM

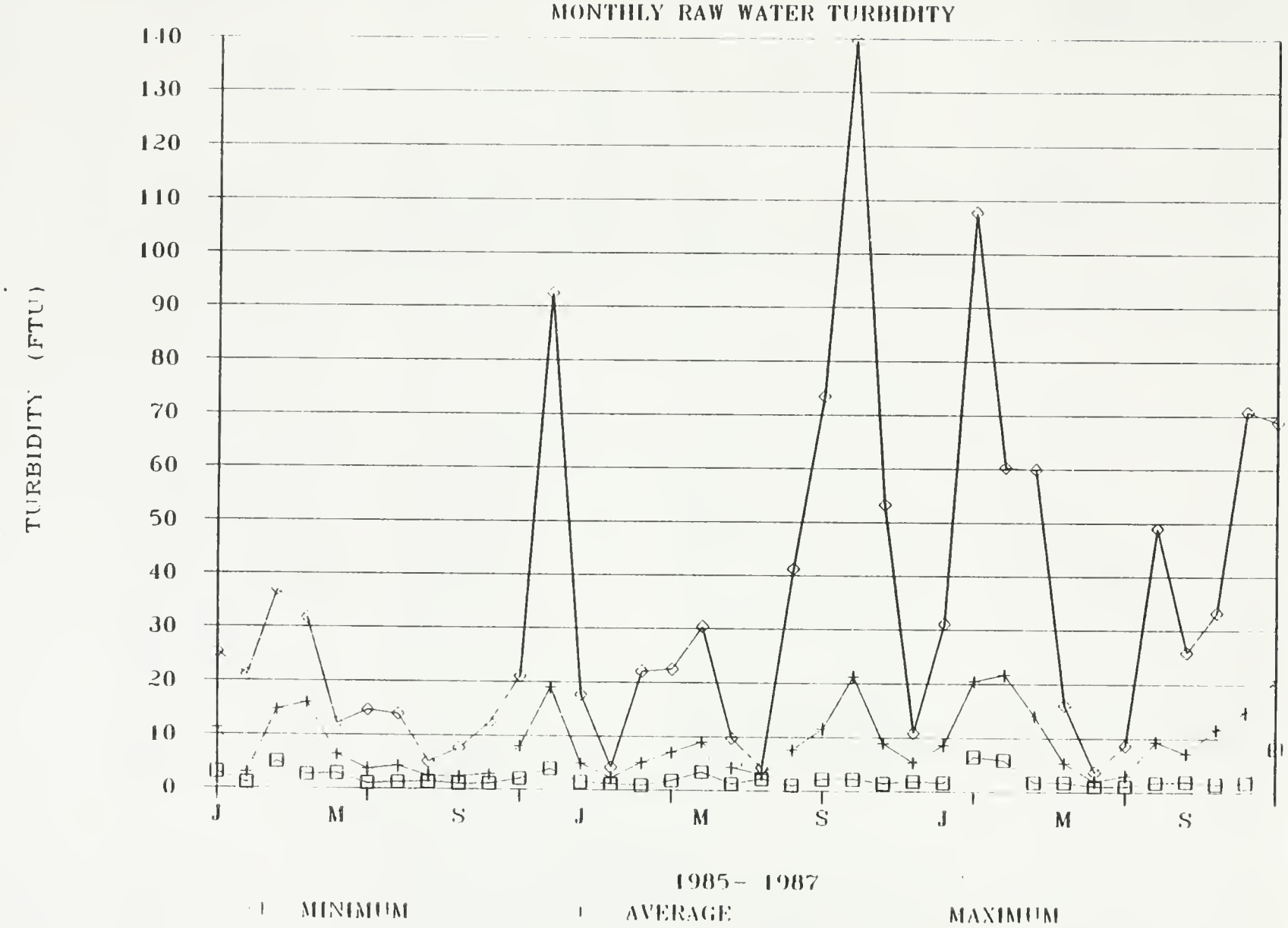


Figure E.1

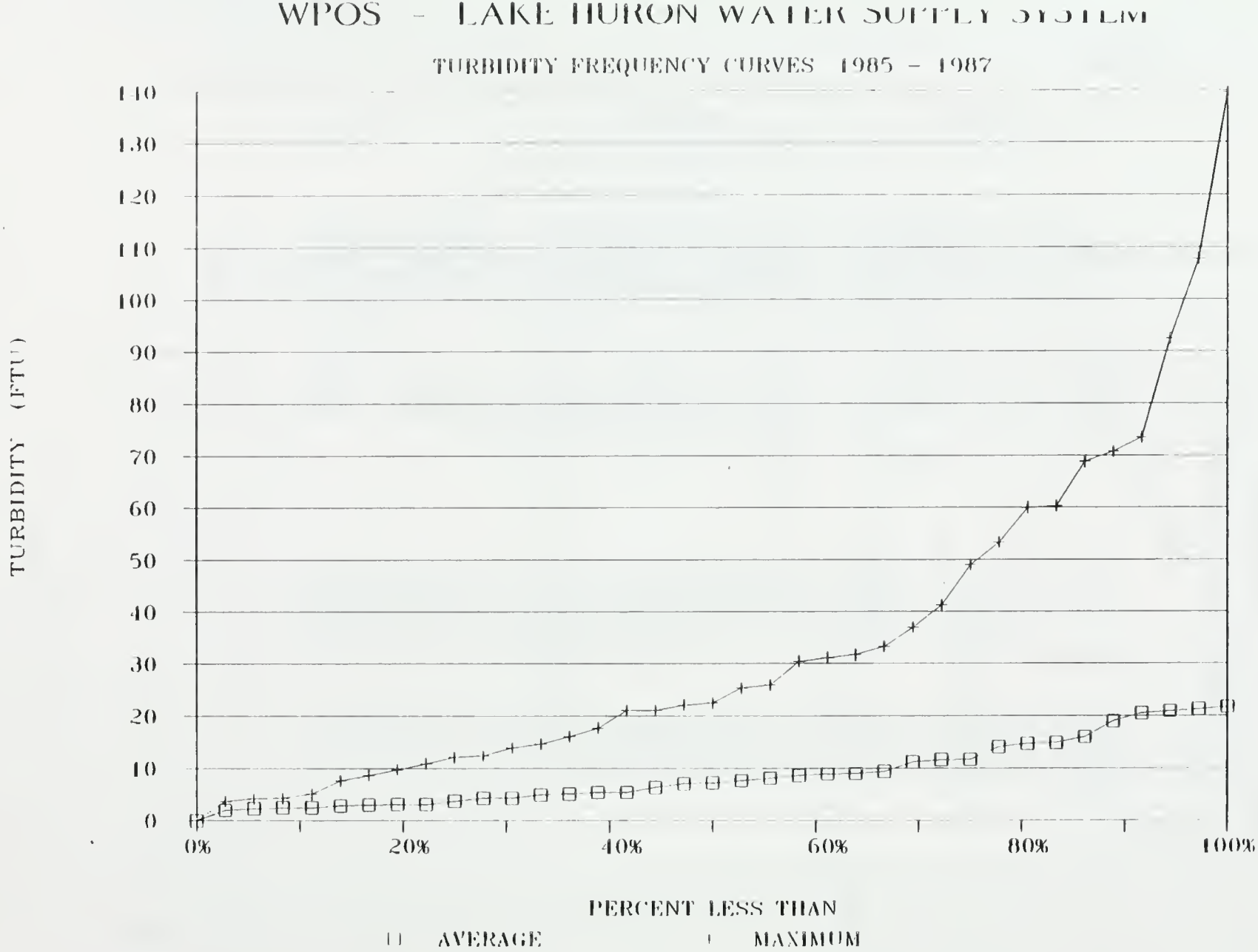

WPOS - LAKE HURON WATER SUPPLY SYSTEM
TURBIDITY FREQUENCY CURVES 1985 - 1987
TURBIDITY (FTU)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0%
20%
40%
60%
80%
100%
PERCENT LESS THAN
AVERAGE
MAXIMUM

Figure E.2

demands occur during June, July, and August, as illustrated in Figure E.3, and do not coincide with the occurrence of high raw water turbidities. Hence during high raw water turbidity events, treatment units are operating at lower flow rates, which minimizes the potential adverse impact on treatment performance due to high solids loadings. Unfortunately, diatom algae blooms occur during May and June, and again in September and October when the lake temperature is between 10 and 15°C. These algae blooms have been particularly troublesome with the direct filtration process and have severely restricted plant capacity in the past.

Operating records reviewed for the plant since October 1986 when sedimentation was added to the treatment process, confirm the production of a high quality effluent without any impairment in filter effluent turbidity, even during adverse raw water conditions. But as mentioned previously, prior to 1986 process modifications, treated water quality deteriorated somewhat during periods of higher than average raw water turbidities. This will be discussed further in the next section.

b) Particulate Removal

The removal of particulate matter is achieved by conventional treatment including chemical coagulation and flocculation followed by sedimentation and filtration. Prior to October 1986, the plant was operated in the direct filtration mode, and flocculated water was applied directly to the filters.

Since November 1986, liquid alum has been used exclusively as the primary coagulant, and no filter aid has been used. During the previous two years alum, ferric chloride, and polyaluminum chloride had all been used at various times, either alone or in combination with one or both of the other two. Two filter aids, both nonionic polyelectrolytes, were also employed during direct filtration treatment. The filter aid Separan NP10 was used from January to March 1985, and Drew 6306A was used from April 1985 to October 1986.

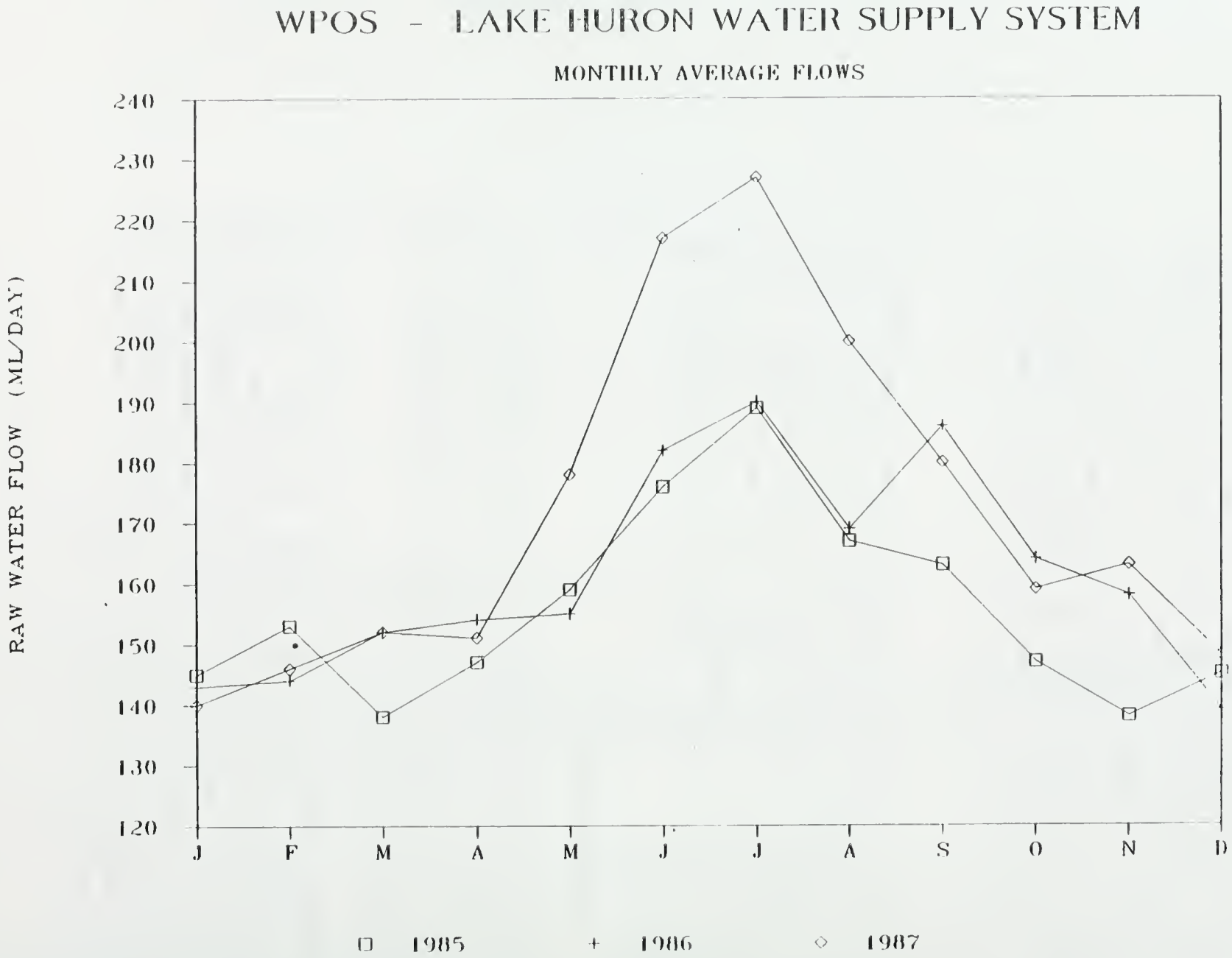

WPOS - LAKE HURON WATER SUPPLY SYSTEM
MONTHLY AVERAGE FLOWS
RAW WATER FLOW (ML/DAY)
240
230
220
210
200
190
180
170
160
150
140
130
120
J
F
M
A
M
J
J
A
S
O
N
D
1985
1986
1987

Figure E.3

During conventional treatment, the alum dosage is selected on the basis of a dosage guide and operating criteria. The actual operating dosage that was applied during conventional treatment is shown graphically in Figure E.4. Daily amounts of alum applied for raw water turbidities varying from 1 to 80 FTU are included for the period of November 1986 to December 1987. The plant dosage guide is depicted by the solid line. The graph indicates that as turbidity decreases, the range of alum dosages applied increases, and that this range is greatest at turbidities between 1 and 10 FTU. With this raw water quality, the alum dose varied from 5.4 to 29.1 mg/L. As raw water turbidity increased to 70 FTU, the maximum dosage of alum remained constant near 20 mg/L, and the minimum dosage increased to 15 mg/L. Reasons for this anomaly are not quite clear. It is known that alum is overdosed during the summer months in order to lower the high raw water pH values. Also, however, there may be times when turbidity consists of very small colloidal matter which is difficult to stabilize at normal alum dosages.

The upper and lower boundaries for alum dosages applied during conventional treatment for raw water turbidities varying from 1.1 to 70.8 FTU are illustrated in Figure E.5. This graph clearly shows the wide divergence in alum dosages that have been used to treat raw water with turbidities ranging from about 1.0 to 50 FTU.

With direct filtration during 1985 and 1986, alum, ferric chloride, and polyaluminum chloride had been used either alone or in combination with each other as the primary coagulant. In addition, a polymer was used at various times as a filter aid.

The coagulant dosages applied during this period have been converted to equivalent metal^{3+} ion dosages expressed in mmol/L and are plotted versus raw water turbidities in Figures E.6 and E.7. The latter figure presents a portion of the overall data at an enlarged scale for increased clarity. The plots shown in these present a similar dosing trend for the primary coagulant during direct filtration as was previously identified for alum during conventional treatment.

For comparison purposes of coagulant dosages applied before and after plant expansion, Figures E.8 and E.9 have been prepared which present

WPOS - LAKE HURON WATER SUPPLY SYSTEM

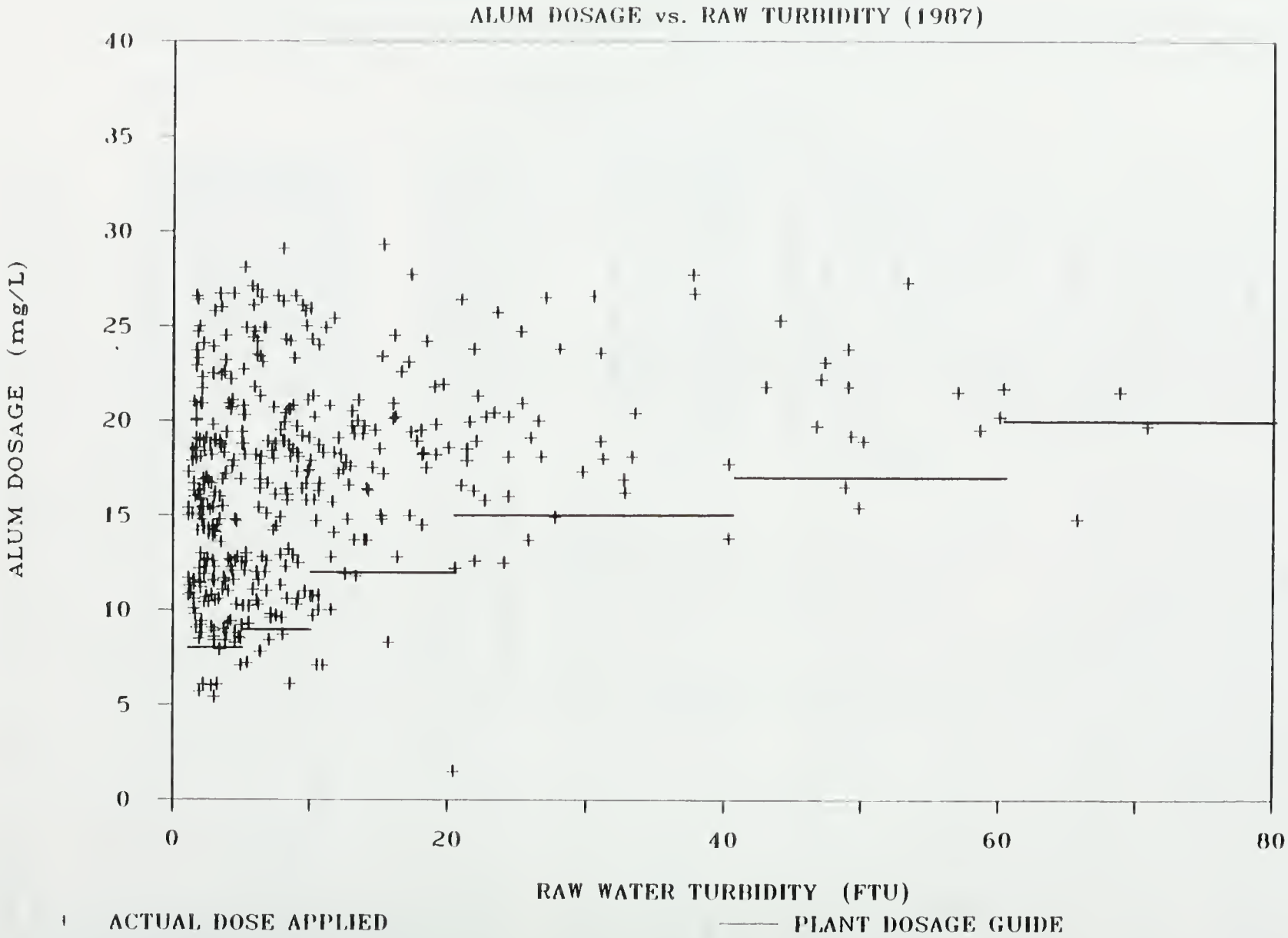


Figure E.4

WPOS - LAKE HURON WATER SUPPLY SYSTEM

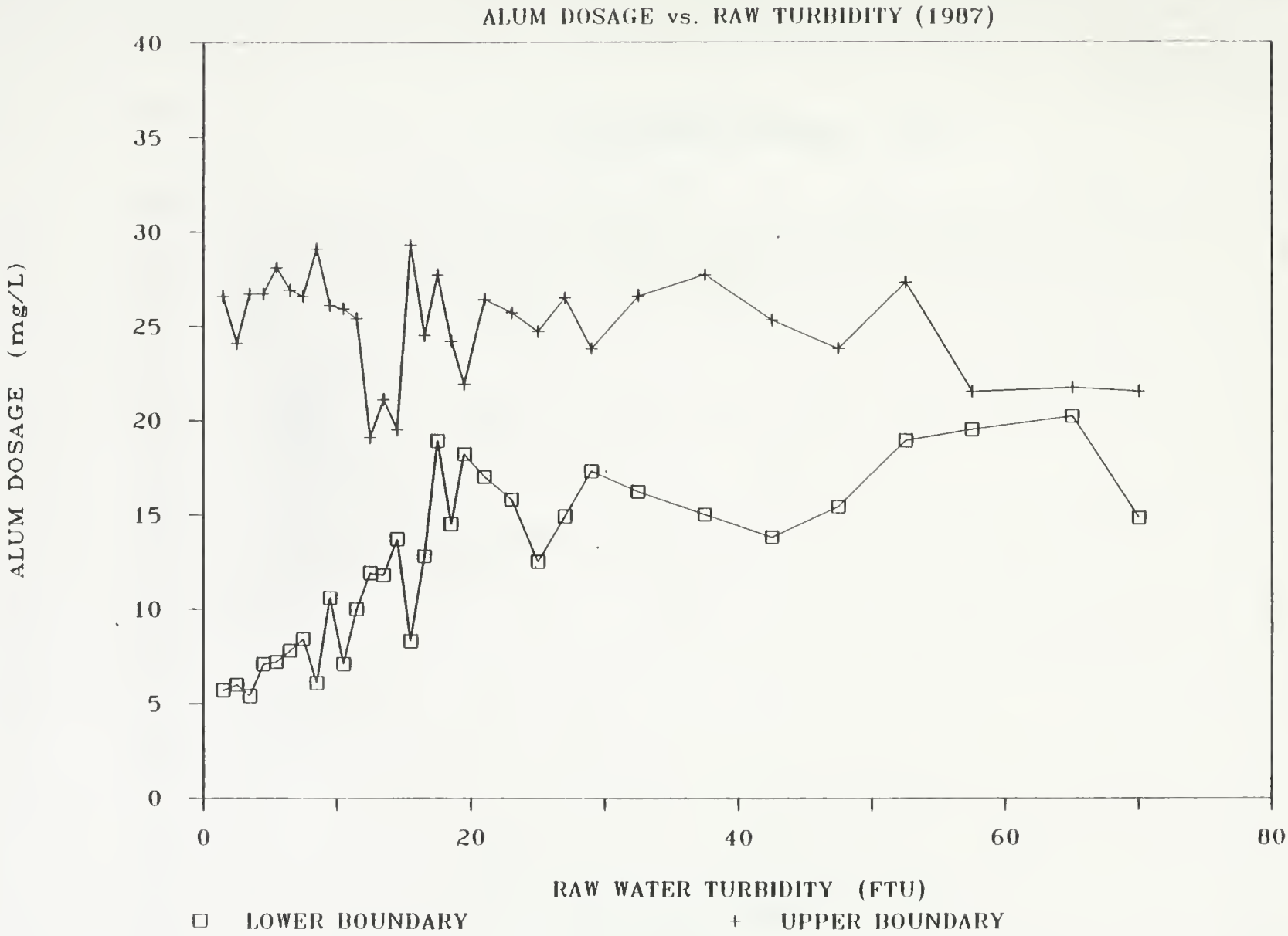


Figure E.5

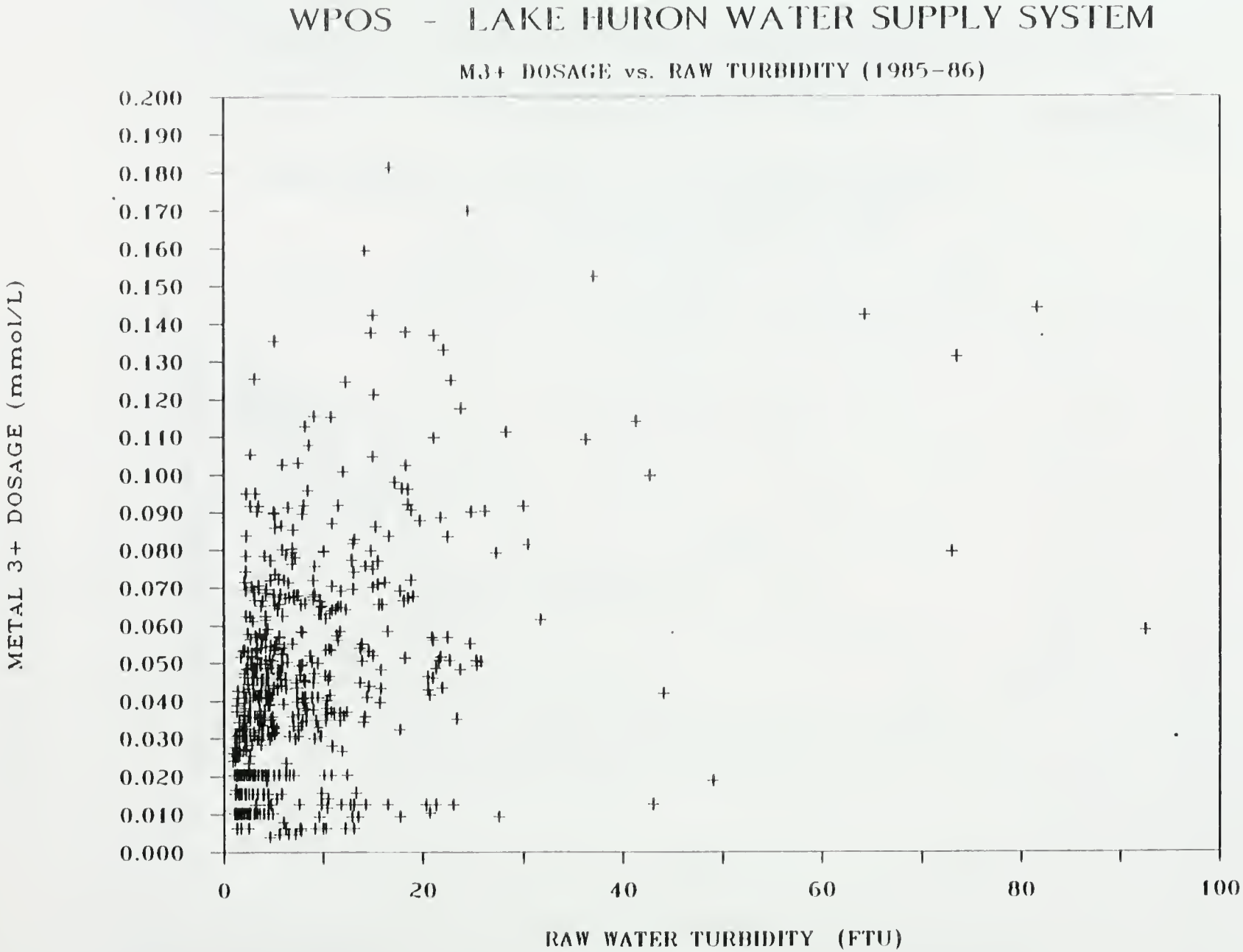

WPOS - LAKE HURON WATER SUPPLY SYSTEM
M3+ DOSAGE vs. RAW TURBIDITY (1985-86)
METAL 3+ DOSAGE (mmol/L)
0.200
0.190
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
20
40
60
80
100
RAW WATER TURBIDITY (FTU)

Figure E.6

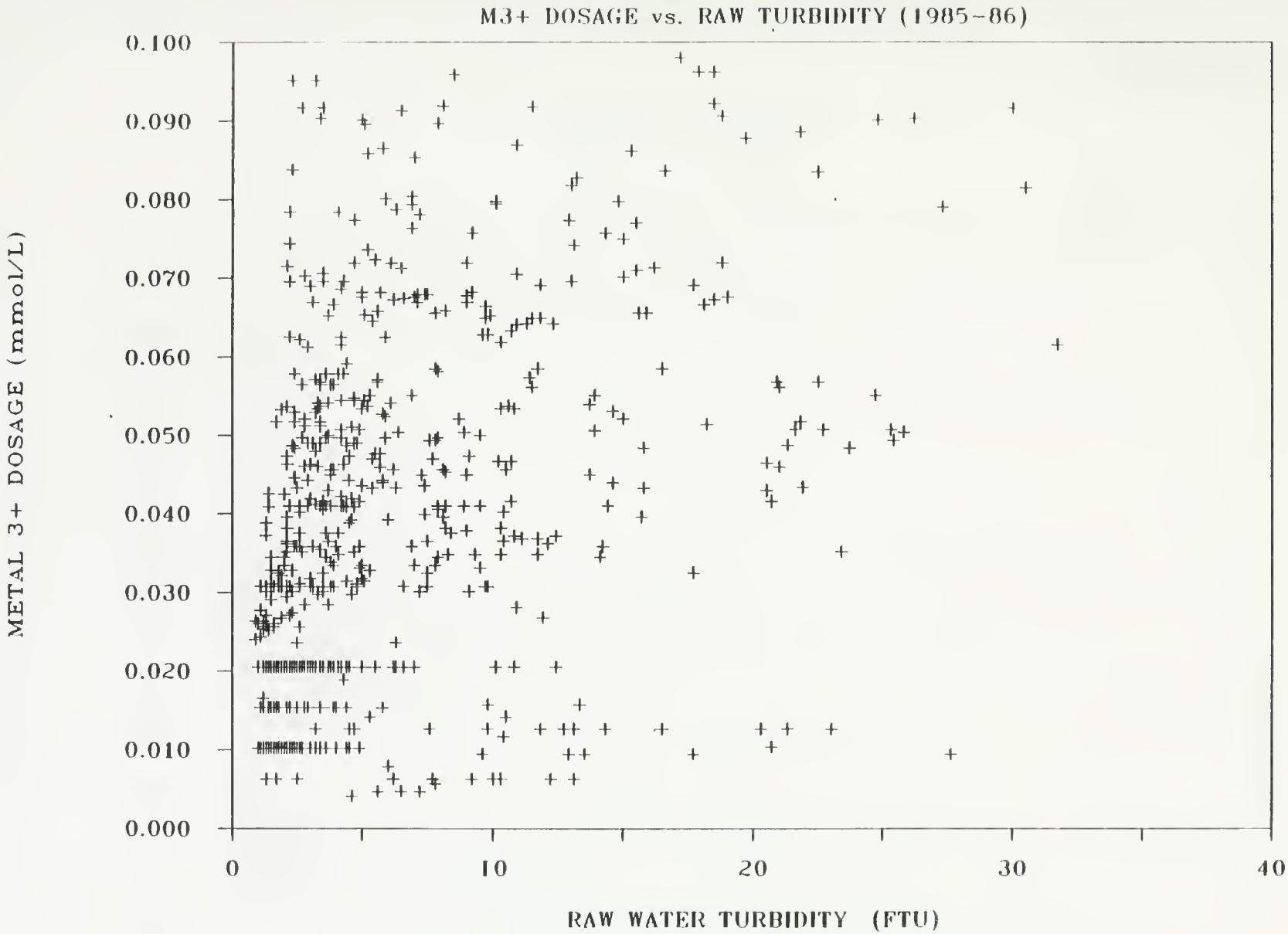

M3+ DOSAGE vs. RAW TURBIDITY (1985-86)
METAL 3+ DOSAGE (mmol/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
10
20
30
40
RAW WATER TURBIDITY (FTU)

Figure E.7

WPOS - LAKE HURON WATER SUPPLY SYSTEM

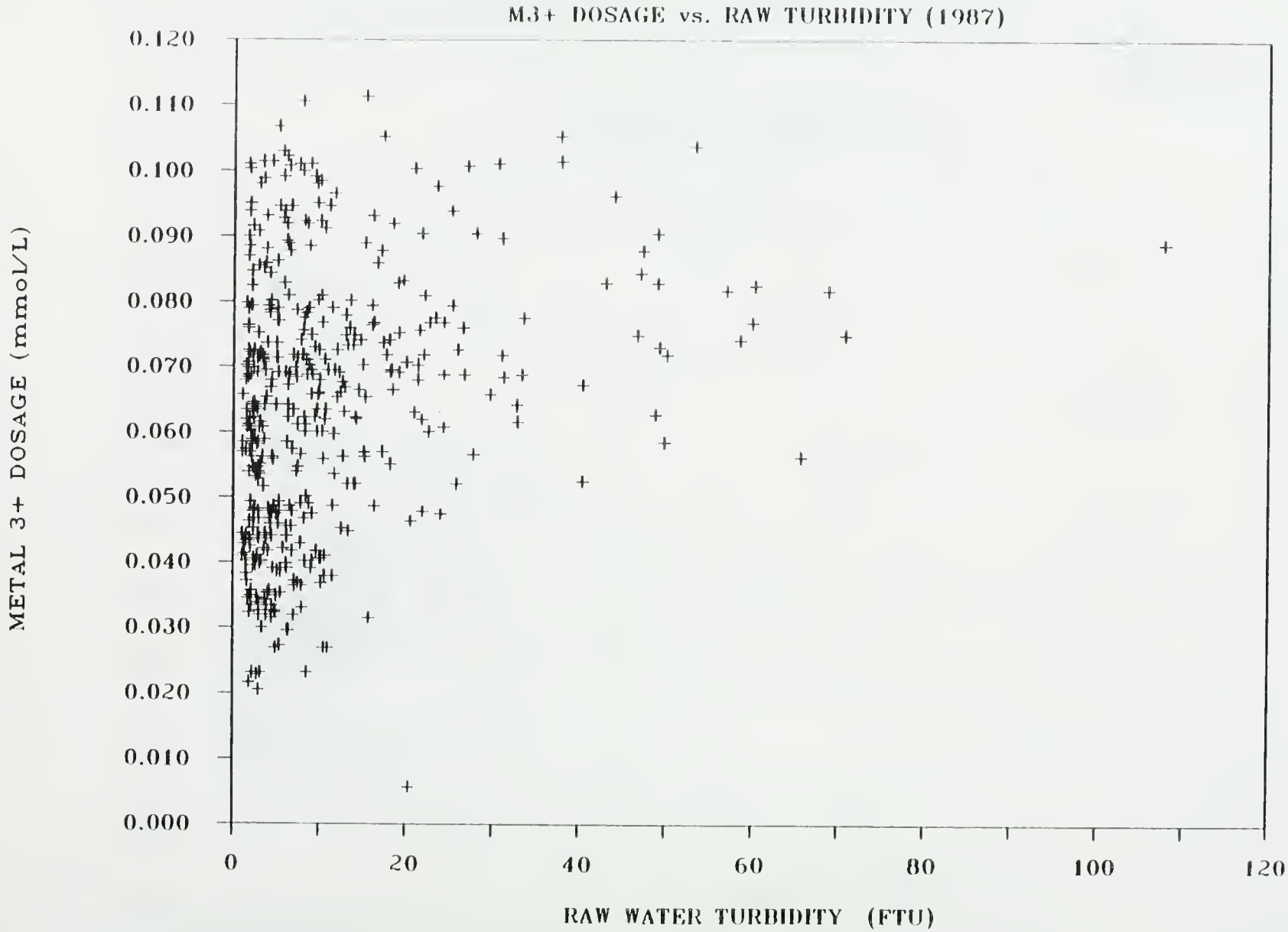


Figure E.8

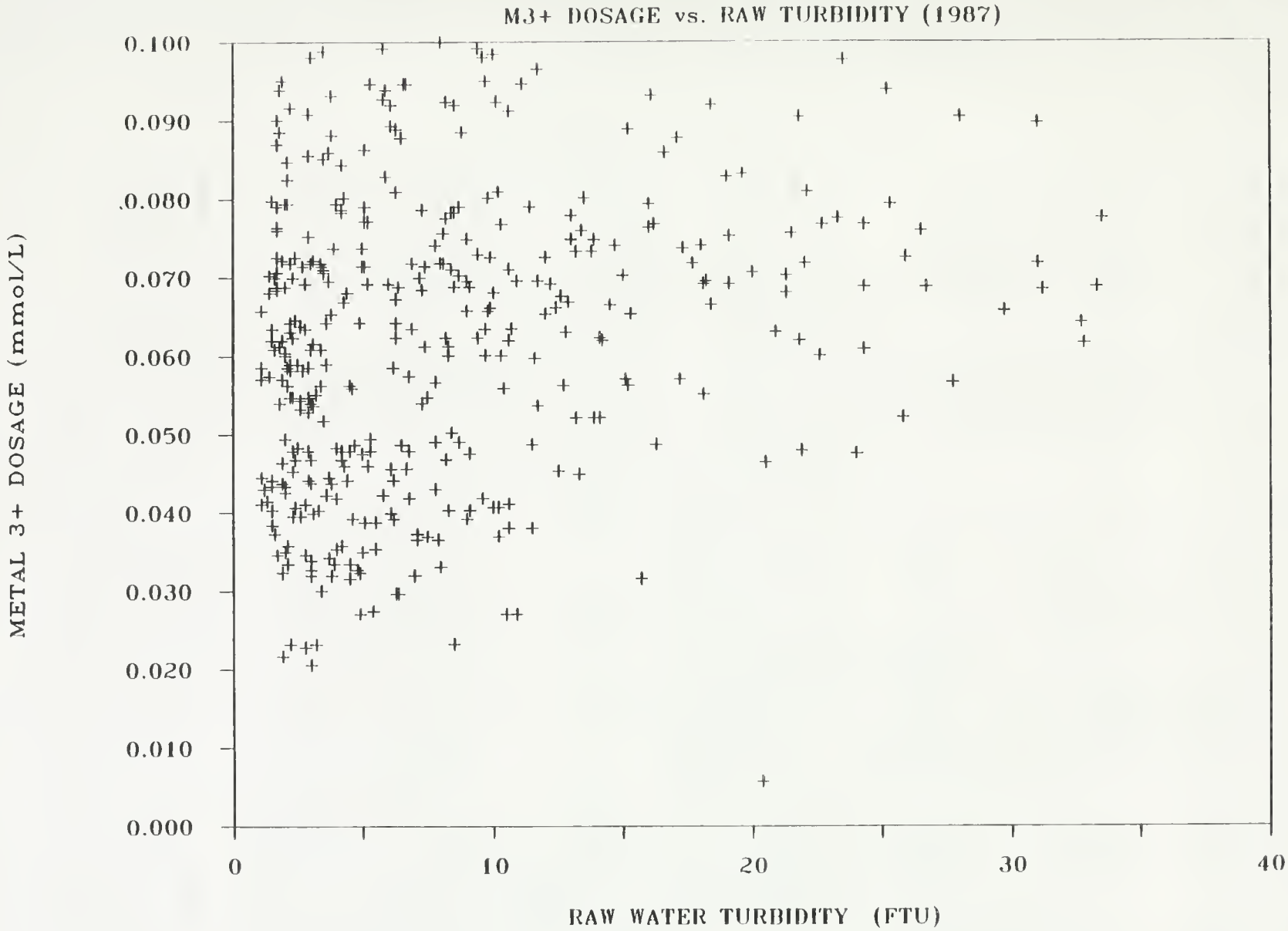

M3+ DOSAGE vs. RAW TURBIDITY (1987)
METAL 3+ DOSAGE (mmol/L)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
10
20
30
40
RAW WATER TURBIDITY (FTU)

Figure E.9

the alum dosages applied in 1987 with conventional treatment in terms of the equivalent metal^{3+} ion dosages in mmol/L. In comparing data of Figures E.8 and E.9 with that for Figures E.6 and E.7, it will be noted that higher coagulant dosages were used with the conventional treatment process.

The overall plant performance with regard to particulate removal was very good when operated in the conventional treatment mode. This is evident from the summary of the operating record presented in Table 2.0 of Appendix D and the graphs of Figure E.10. On a monthly basis, it will be noticed that the turbidity in the treated water ranged from 0.09 to 0.18 FTU. The yearly average value for 1987, including the period of conventional treatment in 1986, was 0.14 FTU.

Particulate removal was also good during operation of the direct filtration plant. Figure E.10 illustrates temporal trends in treated water turbidity. On a monthly basis, treated water turbidity ranged from 0.13 to 0.30 FTU. The yearly average values for the remainder of 1986 and 1985 were 0.20 and 0.25, respectively.

Plant performance on a daily basis is presented in Table 2.1 of Appendix D for January, April, July, and October for each of the three years studied.

Settled water turbidity data are available from November and December 1986, and 1987, for the conventional treatment plant. The average settled water turbidity for this period on a monthly basis was 1.9 FTU, ranging from 1.1 FTU in August to 2.7 FTU in February. Daily average settled water turbidities ranged from 0.7 to 6.1 FTU. These data reflect a high efficiency of removal of particulate matter in the parallel plate clarifiers.

Daily average treated water turibidities during conventional treatment generally ranged from 0.08 to 0.18·FTU. The minimum and maximum value recorded were 0.05 and 0.31 FTU respectively. In January 1987, the treated water turbidity was below 0.1 FTU on 18 of 31 days, and in April 1987, 17 of 30 days recorded less than 0.1 FTU.

WPOS - LAKE HURON WATER SUPPLY SYSTEM

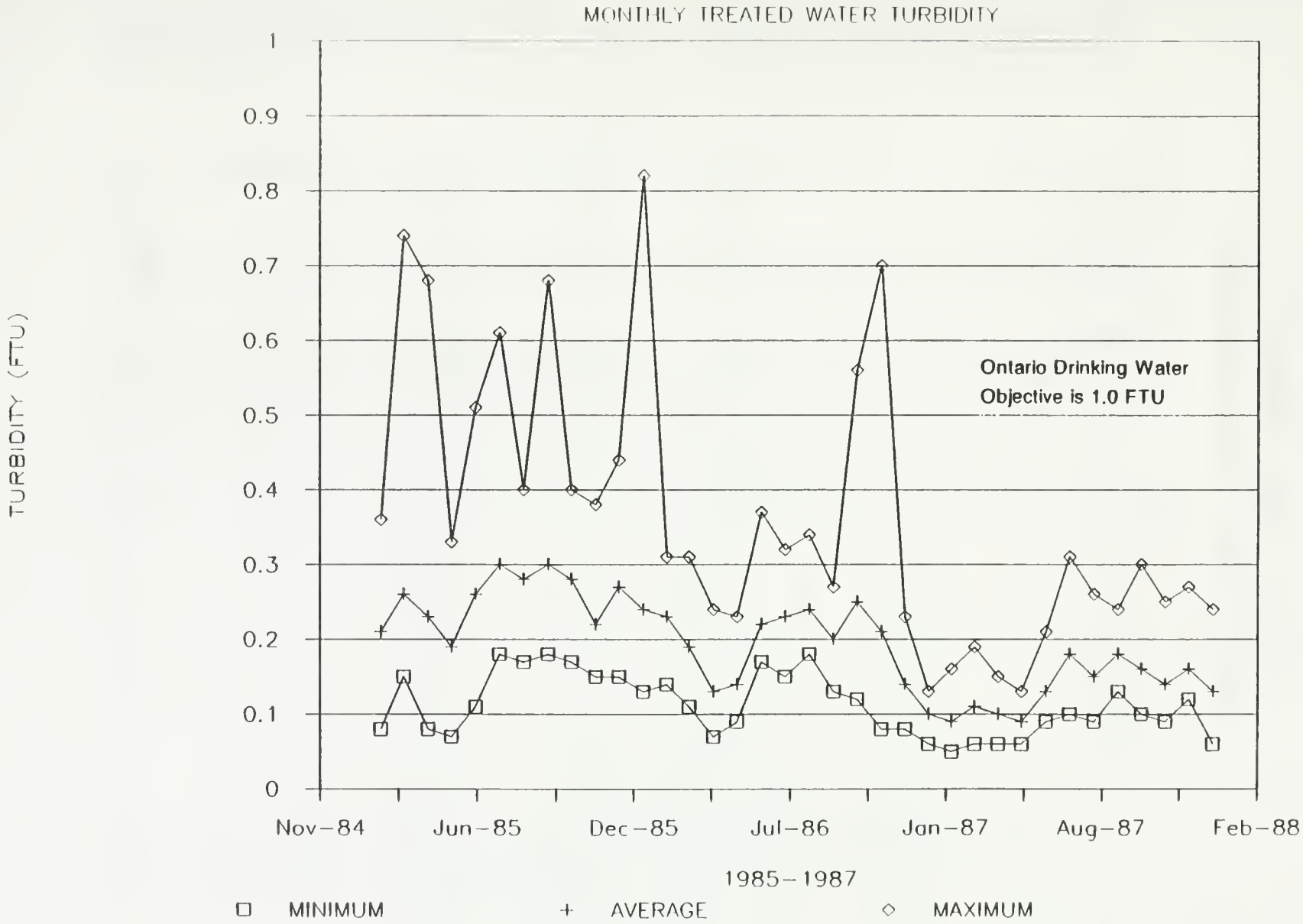


Figure E.10

Treated water turbidity varied more with direct filtration then with conventional treatment. Although the daily averages typically ranged from 0.20 to 0.30 FTU, daily maximums over 0.50 FTU were not uncommon. The highest daily treated water turbidity noted during this phase was 0.84 FTU. The lowest value was 0.07 FTU.

A review of plant performance during periods of high raw water turbidity was carried out. Tables E.5, E.6, and E.7 present plant operating data for periods with high raw water turbidity. Data selection was based on:

- above normal raw water turbidities;
- filtered water effluent higher than normal;
- poor performance of the settling basins.

By examining the data in these tables, it will be noticed that:

- on a daily average basis, filtered water turbidities remained below the 1.0 FTU maximum acceptable concentration at all times over the three year study period;

- during conventional treatment, there was no increase in treated water turbidity even during the most adverse changes in raw water quality;

- during conventional treatment, settled water turbidities increased only slightly during high raw water turbidity events, typically by 1 to 2 FTU over the monthly average value;

- during direct filtration, filtered water quality was subject to deterioration during events of high raw water turbidity. The duration of upset in treated water quality would typically last for only 1 day.

Over the 14 months' period during which conventional treatment was practiced, the average raw water turbidity was 11.0 FTU, and the

TABLE E.5

PLANT PERFORMANCE DURING PERIODS OF

HIGH RAW WATER TURBIDITY EVENTS - 1987

	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
Date	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Jan 22	7.8	1.7	0.09	19.5				143
Jan 23	31.2	2.1	0.09	18.0				144
Jan 24	26.5	2.3	0.11	20.0				142
Jan 25	15.1	1.6	0.12	15.0				143
Jan 26	6.1	1.8	0.12	12.0				144
Feb 07	9.0	2.6	0.12	10.3				148
Feb 08	9.6	2.5	0.13	11.0				78
Feb 09	107.8	2.5	0.12	23.4				144
Feb 10	50.1	4.1	0.10	18.9				168
Feb 11	40.3	3.8	0.11	17.7				148
Feb 12	31.6	3.8	0.12	18.9				149
Feb 13	24.3	3.7	0.11	20.2				148
Feb 14	26.0	6.1	0.08	23.8				146
Feb 15	21.8	5.9	0.09	23.8				147
Feb 16	16.0	2.5	0.09	20.9				149
Mar 01	7.2	1.7	0.09	18.4				146
Mar 02	49.2	1.9	0.09	19.2				143
Mar 03	60.3	1.3	0.07	21.7				153
Mar 04	57.0	1.7	0.10	21.5				154
Mar 05	33.5	2.7	0.09	20.4				154
Mar 06	31.0	3.2	0.15	23.6				152
Mar 07	27.0	2.6	0.13	26.5				151
Mar 08	19.1	1.4	0.06	19.8				154
Mar 09	58.6	2.0	0.08	19.5				152
Mar 10	46.7	2.5	0.10	19.7				154
Mar 11	19.1	1.9	0.08	18.2				153
Mar 12	15.0	1.9	0.08	18.5				147
Mar 30	7.6	1.0	0.12	26.6				153
Mar 31	37.8	1.7	0.11	26.7				151
Apr 01	30.5	2.2	0.08	26.6				147
Apr 02	25.2	1.8	0.07	24.7				148
Apr 03	60.0	1.6	0.06	20.2				149
Apr 04	49.8	3.0	0.10	15.4				141
Apr 05	43.0	2.5	0.10	21.8				148
Apr 06	37.7	2.9	0.11	27.7				149
Apr 07	22.1	2.2	0.06	21.3				148
Apr 08	14.7	2.5	0.07	19.5				150
Apr 09	7.5	1.8	0.06	14.4				150

TABLE E.5 (continued)

Date	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Aug 21	2.8	0.9	0.18	16.7				215
Aug 22	16.6	0.8	0.13	22.6				166
Aug 23	47.3	1.3	0.19	23.1				170
Aug 24	32.7	1.2	0.20	16.9				205
Aug 25	49.0	1.7	0.20	23.8				201
Aug 26	17.3	1.8	0.26	27.7				192
Aug 27	11.7	1.4	0.23	25.4				180
Aug 28	8.8	1.1	0.13	23.3				179
Sep 29	3.0	1.6	0.14	18.9				181
Sep 30	15.3	1.2	0.12	17.2				176
Oct 01	21.5	1.8	0.16	19.9				167
Oct 02	17.3	1.5	0.13	19.4				159
Oct 03	47.0	1.7	0.17	22.2				142
Oct 04	17.1	1.6	0.15	23.1				147
Oct 05	11.4	2.0	0.16	20.8				159
Oct 06	10.9	1.9	0.12	18.3				181
Nov 04	1.9	1.5	0.12	12.2				172
Nov 05	20.5	1.3	0.14	12.2				174
Nov 06	70.8	1.8	0.18	19.7				165
Nov 07	16.0	1.2	0.15	20.1				150
Nov 08	3.7	1.3	0.12	18.3				152
Nov 19	6.7	1.4	0.21	12.0				167
Nov 20	12.5	1.4	0.19	11.9				196
Nov 21	65.7	1.9	0.19	14.8				145
Nov 22	40.3	2.2	0.19	13.8				151
Nov 23	18.1	2.1	0.17	14.5				152
Nov 24	32.8	2.8	0.15	16.2				179
Nov 25	22.7	1.4	0.17	20.2				163
Nov 26	24.3	1.3	0.13	16.0				165
Nov 27	14.1	1.4	0.16	13.7				181
Dec 01	12.7	2.3	0.17	14.8				165
Dec 02	27.7	2.4	0.16	14.9				147
Dec 03	24.3	1.5	0.17	18.1				166
Dec 04	20.0	1.2	0.15	18.6				148
Dec 05	48.8	2.5	0.14	16.5				146
Dec 06	44.0	2.3	0.21	25.3				148
Dec 07	20.9	1.6	0.17	26.4				160
Dec 08	8.5	1.4	0.12	18.1				156

TABLE E.5 (continued)

Date	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Dec 15	8.3	1.9	0.13	15.8				159
Dec 16	26.7	2.4	0.14	18.1				149
Dec 17	68.8	3.3	0.15	21.5				151
Dec 18	49.0	1.8	0.18	21.8				146
Dec 19	25.3	2.9	0.16	20.9				145
Dec 20	12.9	2.0	0.10	17.6				178
Dec 21	21.8	1.9	0.11	16.3				144
Dec 22	10.6	1.8	0.09	16.3				140

TABLE E.6 (continued)

Date	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Aug 23	4.0		0.19		3.0			156
Aug 24	41.3		0.24	18.6	10.0			153
Aug 25	11.8		0.24	14.4	4.0			161
Aug 26	9.0		0.19	14.0	4.0			160
Aug 27	24.8		0.21	20.6	4.0			162
Aug 28	17.9		0.21	20.9	5.0			199
Aug 29	18.5		0.25	22.4	4.0			161
Aug 30	18.5		0.23	21.2	4.0			149
Aug 31	11.5		0.22	21.1	4.0			149
Sep 11	3.4		0.17	14.7				177
Sep 12	2.7		0.26	15.2				176
Sep 13	18.2		0.26	25.5			0.02	182
Sep 14	42.7		0.56	29.7			0.03	195
Sep 15	73.5		0.26	26.8	6.0			177
Sep 16	18.8		0.27	22.4				174
Sep 17	14.3		0.27	22.9				201
Sep 18	12.9		0.22	19.0			0.02	186
Sep 19	11.3		0.22	19.8			0.02	169
Sep 20	9.0		0.44	19.2			0.02	171
Sep 21	11.5		0.36	25.1	6.0		0.03	170
Sep 22	9.1		0.39	27.8	6.0		0.03	179
Sep 23	12.3		0.39	21.4	6.0		0.03	185
Sep 24	7.5		0.14	19.6	5.0		0.03	189
Oct 05	9.6		0.19	18.6	7.0		0.03	160
Oct 06	139.6		0.29	30.5	8.0		0.03	166
Oct 07	81.6		0.27	30.5	6.0		0.03	167
Oct 08	64.3		0.15	33.0				190
Oct 09	73.0		0.17	23.5	7.0		0.03	177
Oct 10	28.3		0.23	22.5	7.0		0.03	158
Oct 11	22.8		0.22	26.4	7.0		0.03	150
Oct 12	14.8		0.33	30.1	4.0		0.03	137
Oct 13	12.0		0.70	23.8	4.0		0.03	153
Oct 14	23.8		0.22	28.7			0.03	170
Oct 15	36.3		0.08	32.3			0.03	161
Oct 16	18.3		0.20	30.3			0.03	159
Oct 17	13.0		0.17	24.2			0.03	165
Oct 18	15.9		0.18	19.4				158
Oct 19	12.3		0.18	19.0				162
Oct 20	10.8		0.22	34.1				158

TABLE E.6

PLANT PERFORMANCE DURING PERIODS OF

HIGH-RAW WATER TURBIDITY EVENTS - 1986

	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
Date	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Jan 25	5.4		0.22	13.9				145
Jan 26	5.8		0.25	13.0			0.01	157
Jan 27	17.7		0.21	9.6			0.01	159
Jan 28	10.4		0.18	10.8			0.01	153
Jan 29	6.6		0.16	9.1				147
Jan 30	4.9		0.16	9.8				155
Mar 11	1.2		0.12	7.7				154
Mar 12	3.7		0.17	8.4				157
Mar 13	22.1		0.24	29.6	4.0	4.0	0.05	165
Mar 14	7.0		0.21	20.0			0.03	158
Mar 15	3.1		0.12	14.5				129
Apr 08	3.0		0.14	9.4				152
Apr 09	10.8		0.15	15.8				157
Apr 10	16.5		0.17	17.3			0.02	166
Apr 11	22.5		0.16	24.7			0.03	156
Apr 12	15.5		0.11	21.0			0.02	150
Apr 13	9.2		0.14	22.4			0.02	149
Apr 14	16.2		0.18	21.1			0.02	160
Apr 15	5.5		0.16	14.1			0.02	154
Apr 16	4.2		0.13	16.1				141
May 01	5.2		0.17	25.4			0.02	131
May 02	30.5		0.19	24.1			0.03	152
May 03	26.2		0.20	26.7			0.01	133
May 04	7.1		0.20	19.8			0.02	140
May 05	11.7		0.25	17.3			0.02	136
May 06	15.0		0.24	31.0			0.02	145
May 07	18.3		0.29	35.2		6.0	0.01	147
May 08	20.7		0.33	6.7		6.0	0.03	162
May 09	15.0		0.37	16.6		6.0	0.03	157
May 10	7.8		0.22	11.7		6.0	0.02	126
May 11	6.9		0.22	17.9		6.0	0.03	157

TABLE E.6 (continued)

Date	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Nov 08	5.0		0.16	18.8				147
Nov 09	19.6		0.17	21.9				161
Nov 10	53.3		0.14	27.3				162
Nov 11	13.8		0.14	19.3				165
Nov 12	13.2		0.12	13.7				157
Nov 13	21.9		0.15	12.6				156
Nov 14	15.7		0.15	8.3				156
Nov 15	6.2		0.15	11.6				155

TABLE E.7

PLANT PERFORMANCE DURING PERIODS OF

HIGH RAW WATER TURBIDITY EVENTS - 1985

	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
Date	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Jan 02	6.6		0.20		4.0			153
Jan 03	15.0		0.33	14.7	4.0		0.06	154
Jan 04	16.6		0.36	18.7	4.0		0.06	159
Jan 05	13.7		0.22	9.9	4.0		0.06	141
Jan 06	13.9		0.23	8.9	4.0		0.06	142
Jan 07	17.7		0.23	14.4	4.0		0.01	143
Jan 08	23.7		0.21	14.3				147
Jan 09	21.8		0.22	15.3				153
Jan 10	7.8		0.26	14.6				154
Jan 14	4.8		0.08	9.2			0.06	150
Jan 15	20.5		0.29	12.7			0.06	158
Jan 16	19.7		0.30	19.9	4.0		0.05	156
Jan 17	13.7		0.21	13.3			0.05	156
Jan 18	9.0		0.20	11.2				137
Feb 26	2.5		0.28		4.6			139
Feb 27	15.0		0.46	33.0	6.0		0.04	160
Feb 28	21.1		0.74	28.4	8.0		0.04	172
Mar 01	5.0		0.14	20.6	1.3			160
Mar 02	5.6		0.28	13.4	0.4		0.06	144
Mar 03	30.0		0.68	27.1			0.07	160
Mar 04	8.7		0.18	15.4			0.08	132
Mar 11	11.5		0.20	16.6			0.04	141
Mar 12	25.8		0.24	14.9			0.08	138
Mar 13	21.8		0.10	26.2				154
Mar 14	14.8		0.20	23.6				147
Mar 15	37.0		0.64	45.1				52
Mar 16								96
Mar 17	24.5		0.22	35.1	10.0		0.07	106
Mar 18	16.6		0.33	38.5	10.0		0.06	121
Mar 19	14.2		0.27	32.0	10.0		0.05	160
Jul 21	2.6		0.23	9.2				151
Jul 22	9.5		0.36	9.8				183
Jul 23	13.9		0.31	16.3				186
Jul 24	10.7		0.29	12.3				204
Jul 25	3.7		0.20	14.7				219

TABLE E.7 (continued)

Date	Average Day Turbidity, FTU			Coagulant Doses, mg/L				Flow
	Raw	Settled	Filtered	Alum	Ferric	PACl	Filter Aid	ML/d
Nov 13	8.2		0.32		8.0			157
Nov 14	21.1		0.39	14.8	8.0	6.0		148
Nov 15	13.3		0.17			5.0		150
Nov 16	4.7		0.15			4.0		130
Nov 27	6.3		0.38		4.0	1.0		146
Nov 28	11.9		0.44		4.0	2.0	0.01	133
Nov 29	20.5		0.34	10.0		4.0	0.02	129
Nov 30	14.3		0.27			4.0		126
Dec 01	12.7		0.41			4.0	0.01	145
Dec 02	16.5		0.23			4.0		155
Dec 03	92.5		0.82	12.2		5.5		172
Dec 04	49.0		0.28			6.0	0.03	164
Dec 05	23.0		0.25			4.0	0.01	154
Dec 06	20.3		0.23			4.0	0.01	143
Dec 07	21.3		0.22			4.0		141
Dec 08	44.1		0.39	8.7		4.0	0.01	155
Dec 09	21.9		0.26	9.1		4.0	0.02	160
Dec 10	13.2		0.23			4.0	0.01	152
Dec 11	9.8		0.21			4.0		154
Dec 12	11.8		0.24			4.0		149
Dec 13	16.5		0.18			4.0		138
Dec 14	43.0		0.23			4.0		143
Dec 15	20.7		0.20			3.3		156
Dec 16	12.9		0.16			3.0		157
Dec 17	27.6		0.26			3.0	0.02	145
Dec 18	17.7		0.21			3.0	0.02	160

average settled water turbidity was 1.9 FTU. The highest average monthly settled water turbidity experienced during conventional treatment was 2.7 FTU in February 1987, when the average monthly raw water turbidity was 20.7 FTU. This represents an efficiency of particulate removal of 87% in these dimentation process. This efficiency decreases slightly during extended periods of low raw water turbidity. These results are indicative of good to excellent removal of particulate matter in the sedimentation basins which can be attributed to adequate capacity in the clarifiers.

Process loading characteristics for various plant flows are tabulated in Table E.8. From the table, it will be noticed that sedimentation tank overflow rates averaged 0.69 m/h, well below the design rate of 1.37 m/h. In comparison, typical sedimentation tank overflow rates for settling of alum floc, as recommended by the AWWA for design purposes, vary from 0.61 to 0.93 m/h, so that such high performance is to be expected. Only during maximum plant flows was the design overflow rate exceeded, and this occurred only during summer months, when raw water turbidity was low.

Jar tests were performed on the raw water to establish the optimum alum dosage. These tests will be discussed later. Jar test results and settling velocity distribution curves are presented in Appendix B. From the settling velocity distribution curves, sedimentation tank overflow rates fall in the range of 0.60 to 1.2 m/h for a raw water of low turbidity. This range is consistent with the recommendation of the AWWA and tends to confirm our conclusion that good particulate removal is to be expected in the sedimentation basins.

Other process loading characteristics given in Table E.8 for the rapid mix tanks and filters are within the acceptable design ranges for these unit operations. The detention time of 22.3 minutes at design flow for the flocculation tanks is marginal for conventional treatment.

Filter performance is generally measured in terms of effluent quality in relation to turbidity; however, the length of filter run is also important in establishing the filter's net water production capability.

TABLE E.8

LAKE HURON WATER SUPPLY SYSTEM

PROCESS LOADING CHARACTERISTICS

Process Unit	1987 Plant Flows, ML/d: Yearly Average 172.0	Maximum Day 357.1	Minimum Day 79.7	Design Flow ML/d 336.4[3]
Rapid Mix Tanks				
- Det. Time, min	1.98	0.93	2.07[1]	1.00
- G Value, s^{-1}	350	350	350	350
- Gt Product	41,580	19,600	43,400	21,000
Flocculation Tanks				
- Det. Time, min	44.1	21.0	47.0[1]	22.3
- G Value, s^{-1}				
. minimum	23	23	23	23
. maximum	65	65	65	65
- Gt Product				
. minimum	60,860	29,000	64,900	30,800
. maximum	171,990	81,900	183,300	87,000
Sedimentation Tanks				
- Surface Overflow Rate, m/h	0.69	1.44	0.64[2]	1.37
- Overall Detention Time, min.	54.4	26.1	58.5	27.5
- Settling Zone Detention Time, min.	14.8	7.1	15.9	7.5
Filters				
- Filter Rate, m/h	5.79	12.00	varies	11.45

(1) 1 tank in service.

(2) 2 tanks in service.

(3) Design flow rate for sedimentation tanks is 340.0 ML/d.

Solids loadings, turbidity, coagulating chemicals and algae, will influence the length of filter runs.

During conventional treatment, filter run lengths averaged 66 hours. From January to April and from September to December, filter runs averaged 72 hours with average head loss of between 1.0 and 1.5 metres. Even longer runs would have been experienced if the filters had been operated to terminal head loss of 2.4 m. The shortest filter runs were experienced in July, when 2.1 meters of head loss were developed in 46 hours. The decrease in filter run length during summer months coincided with higher plant flows, despite slightly lower settled water turbidities during this period. It maybe concluded that the decrease in length of filter run was partially attributed to a nominal amount of algae carry-over from the clarifiers.

The length of filter runs during direct filtration averaged 34 hours, and ranged from 16 hours in May 1986 to 53 hours in October 1985. Shorter filter runs coincided with higher plant flows and higher algae counts. Filters were backwashed when head loss reached 2 metres.

By November 1986, conventional treatment was being practiced, and the immediate benefits that were obtained included:

- increased reliability in plant production of the design flow rate 100 percent of the time;
- elimination of secondary coagulant(s) requirement;
- elimination of filter aid requirement;
- lower solids loading to the filters;
- longer filter runs;
- lower consumption of filter backwash water;
- improved treated water turbidity;
- improved reliability of treated water turbidity, especially during upsets in raw water quality.

c) Treatability Tests

Jar tests were performed on Lake Huron water taken from the Lake Huron plant on March 10, 1988. Two tests were carried out to establish the

optimum alum dosage for treatment. Parameters evaluated in selecting the optimum dosage included: time to visibility of first floc, floc appearance' floc size and quantity, settling velocity, and turbidity of filtrate from a laboratory glass fibre filter paper.

Test procedures and results are presented in Appendix B. Results for settled water turbidity are plotted in terms of settling velocity distribution curves for each test. Settling velocities measured ranged from 6 cm/min. (3.6 m/h) to 0.47 cm/min. (0.28 m/h). A plot of the filtered water effluent turbidity versus the coagulant dosage applied in each jar is also presented in order to graphically illustrate the effect of coagulant dosage on the filterability of the pretreated water.

The raw water quality for the two tests was as follows:

	Jar Test 1	Jar Test 2
Turbidity, NTU	1.17	1.17
Colour, ACU	10	10
Temperature, oC	2.1	2.2
pH, units	7.94	7.96

Test 1 established the range for the optimum alum dosage to be between 8 and 16 mg/L based primarily on a consideration of filtered water turbidity. In view of the low raw water turbidity, settled water turbidity was not a good indicator for selecting the optimum dosage. As can be seen from the settling velocity distribution curves for Test 1, a dose of 8 to 12 mg/L or higher also gave good settling of floc at moderate to high velocities. However, lower doses still formed a filterable floc, and resulted in good filtered water turbidities. This is evident from Test 1, where a good filtered effluent quality of 0.18 NTU was achieved with a dose of 4 mg/L. For a settleable floc, filtered water effluent quality improved with an alum dose of 10 mg/L.

With a dosage of 10 to 12 mg/L, an acceptable settling velocity in the jar would be 1.2 to 2.4 cm/min., or 0.7 to 1.4 m/h. For design purposes, this settling velocity would translate to a maximum sedimen-

tation tank overflow rate of 0.35 to 0.7 m/h based on a scale-up factor of 50 percent.

Experience has shown that the glass fibre filters used in the jar tests give results that are very close to the performance of full scale dual media filters.

d) Capability of Existing Plant

Since the plant expansion, a maximum day raw water flow of 357. 09 ML/d was recorded for July 31, 1987. This treatment rate exceeded the design capacityof the plant by 6.2 percent. The operating record for this day was as follows:

- raw water quality:	
. turbidity, FTU	3.5
. pH, units	8.80
. temperature, °C	22
- alum dosage applied, mg/L	18.7
- treated water effluent turbidity, FTU	0.17
- number of filter backwashes (for 2.4 m ave. head loss and 23 h runs)	13.0
- percentage of wash water used	3.0

In spite of the high flow rate, an excellent water quality was produced. The wash water consumption was above average for conventional treatment and reflects the increased number of backwashes that were required to maintain filter operation. The average length of filter run was 23 hours which is still favourable from an operating point of view. The results lead to the conclusion that the plant is capable of achieving the design flow capacity under prevailing raw water quality conditions.

The direct filtration plant in 1985 and to October 1986 was restricted in capacity by high solids loadings to the filters as a result of 1) high raw water turbidities, 2) the need for application of high coagulant dosages, and 3) large numbers of algae in the raw water. Under such adverse raw water quality conditions, the filter effluent turbi-

dity would increase above normal, but remain below the 1.0 NTU objective. Of far greater concern, however, was the impact of high solids loadings to the filter on plant operations. The filter head loss would build up rapidly resulting in filter runs as short as 5 hours during June 1985 when the maximum flow treated was only 225.8 ML/d or 67 percent of the design rate. In addition, the amount of backwash water consumption exceeded 30 percent of the treated water. Under such conditions, plant operations cannot be sustained and it becomes necessary to reduce the treatment rate.

E.2.2 Optimum Performance Alternatives

The operational record, reviewed and discussed in the previous section, indicates that a high level of particulate removal is being achieved by the treatment plant. Several alternatives that might further improve the removal of particulate matter include the following:

Alternative 1 - Plant Hydraulic Distribution Study

Equal split of flow to the parallel systems should be ensured. Unequal flow to parallel processes may result in the overloading of one treatment train with subsequent deterioriation in performance. Flow distribution can be determined either by in-line flow meters, or by a tracer study. A tracer study has the advantage in that it can also detect and quantify short- circuiting during the various treatment processes.

The plant operating records should be occasionally scrutinized for poor performance by the individual settling basins as a possible indication of unequal flow distribution to the units.

Alternative 2 - Primary Coagulant Selection

Alum has been the only primary coagulant used since the plant has been operating in the conventional treatment mode. An evaluation of the amount of coagulant used in relation to raw water turbidity suggests

that alum has not been applied according to the plant dosage guide, and that excessive amounts might have been (and may continue to be) added during low raw water turbidity conditions. Therefore, a comprehensive jar test program should be undertaken to: 1) re-evaluate the plant dosage guide for the use of alum, and 2) evaluate the performance of alternate coagulants with the conventional treatment scheme. Several studies in the technical literature indicate that ferric chloride and polyaluminum chloride can out perform alum with respect to particulate removal for certain raw water conditions, including influent temperature below 4°C. Cationic polymers should also he evaluated for use as the primary coagulant. Seasonal tests should be included in the evaluation so that all raw water conditions are encompassed.

Alternative 3 - Coagulant Dosage Control

The streaming current meters should be calibrated based on the results of the comprehensive jar test program. The output from the SCM should be transmitted to a readout device in the control room so that operators have instant and continuous information to guide adjustment of coagulant dosage. Alternatively, and preferably, the signal can be used to feedback to the coagulant feed pumps and automatically adjust dosage to changing raw water conditions.

Alternative 4 - Coagulant Aid

The use of secondary coagulants should be evaluated as part of the jar testing program already discussed. The use of polymers may lead to a reduction in the required dosage of primary coagulant, and may also improve filter effluent quality. Since use of polymers can lead to a more dense floc, head loss development can be slowed if these secondary coagulants are properly used. Nonionic, anionic, and cationic polymers should all be evaluated.

Alternative 5 - Addition Point of Coagulants

In order to make more efficient use of the coagulants, they should be added to the rapid mix tanks at a point near the hub of the impeller. This will ensure the fastest and most complete dispersion of the chemicals.

In addition, if a secondary coagulant is to he used, the importance of the sequence of coagulant addition, if any, should be evaluated. If sequencing is found to be important, then addition points to each of the serial chambers in the rapid mix reactors should be installed and utilised accordingly.

Alternative 6 - Rapid Mixer and Flocculator Energy Adjustment

Seasonal changes in plant flows result in raw water temperature variations and changes in the detention time in all process tanks, including the rapid mix reactors and the flocculators. Tests should be carried out to establish the energy input to both of these processes that will result in the optimum Gt product.

The benefits of tapered energy input to the primary and secondary flocculator zones should be established, and if found to be advantageous to process performance, tapered flocculation should be implemented. This will encourage particle collisions in the first zone, prevent floc breakup in the secondary zone, and can be tailored to produce floc of variable size. An energy input that results in the best filtered water quality is desired.

Alternative 7 - Filter Aid

A nonionic polymeric filter aid added to settled water just as it enters the granular filter beds can improve effluent quality by enhancing particle attachment within the bed. This can also help to prevent breakthrough from occurring prior to the onset of terminal head loss.

The benefits of using a nonionic polymer filter aid should be evaluated at the Lake Huron plant.

Alternative 8 - Filter Operation

The performance of the dual media, high rate filters may be improved on a continuous basis by:

(1) minimizing hydraulic surges by utilizing ramp controlled valve operators;

(2) using a nonionic filter aid to improve the efficiency of the filter and to prevent early breakthrough (as mentioned above);

(3) adding a coagulant (either a metal salt or polymer) to the filter backwash water to reduce the initial high effluent turbidity and filter ripening period;

(4) modifying filter effluent piping to permit filtering to drain at start-up;

(5) allowing a filter to rest for about 15 minutes after a wash before reinstatement into service;

(6) ensuring that filters are operated continuously from the beginning of a run until terminal head loss is reached, then washed, to prevent dirty filters from being restarted;

(7) not using the common practice of decreasing head loss across filters during cold water conditions by "burping" the media, which releases trapped gases that evolve in filter beds.

Hydraulic Flow Surges

Hydraulic flow surges generally result in deteriorated filter effluent quality by causing the release of previously removed particles, fibers, cysts, etc. Surges can occur in on-line filters due to a sudden change in flow rate as a result of increased pumping or when a filter is taken out of service for backwashing. These surges may be as critical to filter effluent quality as is the hydraulic surge that occurs during start-up of a filter.

Surges in on-line filters can be minimized by maintaining the maximum number of filters in operation, thus filtering at the lowest possible rated and by minimizing the rate of change of raw water pumping.

Upon start-up of a washed filter, the initial hydraulic surge can be minimized by gradually opening the rate control valve. This can be achieved automatically by installing ramping-type valve operators on filter control valves.

Filter Conditioning

Conditioning a filter by adding a coagulant (metal salt or polymer) to the wash water for the duration of the backwash cycle needed to displace the volume of water in and above the dirty filter may reduce the peak and duration of the initial higher effluent turbidity in the filter ripening sequence.

It is suggested that trials be carried out to establish the feasibility of this alternative for implementation at the Lake Huron plant.

Filter to Drain

A further alternative for reducing the initial filter breakthrough after start-up is to filter to drain. Special filter effluent piping equipped with automatically controlled valves may be required for implementation of this alternative. Filtering to drain would increase the time a filter being washed is out of service and increase the wash water consumption by 20 to 50 percent, depending on the length of the filter ripening sequence.

It is suggested that the feasibility and benefit of filtering to drain be established by full-scale testing at reduced filter rates using the manually controlled filter drain pipe.

Filter Rest Period

The assumption is that during a rest period of 15 minutes or longer, the filter media will compact and return to conditions similar to those prior to backwashing.

Restarting Filters

The restarting of a filter that has not been backwashed since being removed from service can lead to the same problem of release of contaminants from the filter bed discussed previously for hydraulic flow surges. This can be a problem even for filters that have been in service for only a few hours during daily peak demand. Filters should be run continuously from the start of a run until terminal head loss is reached.

Filter Burping

The burping of a filter bed while in service can result in serious contaminant breakthrough in addition to physical disruption of the filter bed and/or support gravel.

Alternative 9 - Continuous Monitoring

Continuous monitoring of the effluent of all individual on-line filters allows operators to better know the status of the filters and provides an early warning system in case of filter failure. This knowledge, in addition to the continuous monitoring of streaming current discussed above, will enable operators to produce the best quality water possible at all times.

E.3 DISINFECTION

E.3.1 Process Evaluation

a) Chlorination Equipment

The plant includes a separate Chlorine Building equipment with storage and feed facilities for chlorine gas.

The gaseous chemical feed equipment is described in Section C.4.2 and summarized in Table C.1.

b) Application Points

Chlorine gas in solution form is applied through an open channel diffuser for prechlorination at the surge well of the Low Lift Pump Station. Alternate application points are in the North and South Rapid Mixers, or in the North and South Raw Water Conduits when bypassing the pretreatment train. Postchlorination is applied through open channel diffusers in the North and South Filtered Water Conduits.

c) Dosages and Control

A record of the plant's disinfection practice is presented in Tables 3.0, 3.1, 4.0, 4.1, and 6.0 of Appendix D. Table 3.0 presents a monthly summary for the years 1987, 1986, and 1985. A daily disinfection profile is presented in Table 3.1 for January, April, July and October for each of the three years studied. An overall water quality summary is given in Tables 4.0 and 4.1, while bacteriological test results are documented in Table 6.0 on a monthly and yearly basis for 1987 to 1985.

Table E.9 following presents a 3-year summary of the chlorine dosages applied and resultant chlorine residuals. On average, the pre-chlorine dosage was 0.67 mg/L for 1987, 0.78 mg/L for 1986, and 0.76 mg/L for 1985. The overall range was from 0.52 to 1.12 mg/L. Pre-chlorine was not added during June of 1987, from May to August 1986, and during July 1985. The post-chlorine dosages in Table E.9 indicate yearly average chlorine dosages of 0.92, 0.99 and 0.79 mg/L for the years 1987, 1986, and 1985 respectively. The range of dosages was from 0.31 to 1.80 mg/L.

Dosages for prechlorination and postchlorination feeders are set manually and automatically paced proportional to raw water and total filtered water flows for respective North and South Bank Filters. A detailed description of the control of chemical dosages is given in Section D.5, Item b).

TABLE E.9

CHLORINATION - 3-YEAR SUMMARY

Parameter (1)	1985			1986			1987		
	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
Prechlorination (2)									
- dose	0.52	1.12	0.76	0.49	1.04	0.78	0.22	1.02	0.67
- free residual	0.35	0.90	0.55	0.29	0.72	0.51	0.35	0.70	0.50
Postchlorination									
- dose	0.31	1.80	0.79	0.51	1.80	0.99	0.49	1.70	0.92
- total residual	0.50	1.10	0.96	0.29	1.10	1.01	0.82	1.33	1.02

(1) All results in mg/L.

(2) Prechlorination results are based on results from:
11 months in 1985
8 months in 1986
11 months in 1987.

d) Chlorine Residuals

The pre-chlorine residual is monitored by grab sample and analyzed manually by titration in the laboratory as mg/L free chlorine. The average free chlorine residuals for 1987 to 1985 were 0.50, 0.51, and 0.55 mg/L respectively and ranged from 0.29 to 0.90 mg/L.

The total chlorine residual is monitored by grab sample and analyzed manually in the lab as for the pre-chlorine residual. The yearly summary in Table E.9 shows average total chlorine residuals of 1.02, 1.01, and 0.96 mg/L for 1987 to 1985 respectively and a range of 0.29 to 1.33 mg/L for the three years.

e) Process Evaluation

The pre-chlorine dose is selected to meet the plant's objective of maintaining about 0.5 mg/L free chlorine residual in the filtered water. For an average chlorine dosage of about 0.73 mg/L and an average free chlorine residual of 0.52 mg/L experienced over the study period, the chlorine demand is about 0.21 mg/L. This chlorine demand is fairly constant but will vary somewhat with the seasonal changes in raw water quality. From Table 3.0 for instance, it will be noticed that the chlorine demand increased in September 1986 to 0.43 mg/L.

The chlorine is applied in the Low Lift Station and has a contact time prior to entering the filtered water conduit of about 4 hours at the design flow rate. Under these conditions the plant enjoys the maximum benefits of the prechlorination process. The inefficiency resulting from the high pH of the source water (usually above 8.0 and as high as 8.8) is compensated for by the long contact time.

One disadvantage of the prechlorination process is the potential for forming trihalomethanes. However, based on results of the MOE DWSP program, the levels of total THMs formed at the Lake Huron plant are very low, in the range from 29.0 to 40.8 ug/L in 1986 to 1987, and prechlorination is not a problem in this regard.

Postchlorination serves as the final disinfection process. Contact time is provided by the Clear Well which has a volume of 6640 m^3. At

the design flow rate this volume provides a theoretical detention time of 28 minutes. Good contact is ensured by the longitudinal flow path through the two sections of each half of the Clear Well. Water delivered to consumers closest to the plant has a minimum detention time of 35 minutes at design flow, while water transmitted to the London area has a total detention time of approximately 9.4 hours.

At the levels of chlorine dosage and contact time described above, the chlorination process is highly efficient. However, since kill effectiveness is dependent on pH and temperature as well as on chlorine dose and contact time, variations in the efficiency of disinfection are to be expected. The actual performance achieved during the study period with respect to the normal indicator bacteria used for defining bacteriological water quality is discussed below.

Data on bacteriological water quality, raw and treated, are presented in Tables 6.0 to 6.2 for 1987 to 1985 respectively. For each of the three years studied, all tests for total coliform organisms in treated water were negative. For 1987, two tests for fecal coliform and one for fecal streptococcus organisms were positive. All other tests during 1986 and 1985 were negative.

Following postchlorination, the pH of the plant output is anywhere from 0.2 to 0.9 units lower than the raw water pH. This decrease in pH is the result of chemical coagulation and chlorination of the water. For 1987 the average treated water pH was 7.5 units, while the range for the three year period was 6.7 to 8.1 units. Higher treated water pH values occur during warmer weather. The effect of both high pH and high temperature tend to reduce the disinfection efficiency and a downward adjustment of pH of the raw water maybe desirable to improve the efficiency of disinfection during the summer season.

E.3.2 Capability of Existing Plant

The existing practice of pre- and postchlorination is very effective in producing a high quality water free of microorganisms. The practice should be continued in the future for disinfection of Lake Huron water.

Sufficient equipment is available to treat the maximum hydraulic flow rate through the plant.

E.3.3 Optimum Disinfection Procedures

Having reviewed the existing chlorination practice in detail, it was found that no modifications are required to be undertaken at this time to improve the process.

E.4 OTHER CONCERNS

E.4.1 Taste and Odour Control

During analytical testing in the lab, the operators informally monitor the treated water for objectionable tastes and odours by simply tasting and sniffing a sample drawn from the tap. No problems were reported to exist with taste and odour in the treated water at the Lake Huron plant during the study period. However, with high algae counts in the raw water during the summer months, objectionable tastes and odours were previously encountered following prechlorination treatment. For this reason, and as a precautionary measure against the recurrence of this problem, prechlorination is now not practiced during the summer months.

E.4.2 Aluminum and Iron in Treated Water

The aluminum and iron content of treated water is analyzed in the plant laboratory by spectrophotometer. Results are tabulated in Table 2.0 in terms of monthly maximum, minimum and average values. Raw water samples are not analyzed for these metals.

For the treated water, the dissolved aluminum and iron content was as follows:

	Treated Water Characteristics		
	1987	1986	1985
Aluminum, mg/L			
- Range	0.00 - 0.21	0.00 - 0.17	0.01 - 0.23
- Average	0.063	0.053	0.059
Iron, mg/L			
- Range	0.00 - 0.18	0.00 - 0.12	0.00 - 0.08
- Average	0.011	0.018	0.023
pH, units			
- Range	7.11 - 8.12	6.87 - 7.99	6.72 - 8.09
- Average	7.71	7.75	7.61

At pH 7.7 the solubility of aluminum hydroxide species in a pure system is about 0.27 mg/L Al (Amirtharajah and Mills, 1982 after Rubin & Kovac, 1974), and can be 10 to 100 fold higher in natural waters. The average aluminum residuals in the plant output were quite low, and well below the saturation level in a pure system at pH of 7.7. Although a detailed discussion of this subject is beyond the scope of this report, extensive information on aluminum residuals in drinking water is available in the technical literature. A maximum concentration of 0.10 mg/L as Al has been suggested by the Ontario Drinking Water Objectives as a guideline for minimizing problems in the distribution system related to post-precipitation of aluminum hydroxide floc.

The residual iron concentrations are generally very low. The positive iron residual results observed are likely the result of the presence of iron in the raw water. Low dissolved iron is expected as the solubility of iron hydroxide species is near a minimum at the treated water pH values experienced at this facility.

E.4.3 Optimization of Coagulation Processes

Since the optimum pH range for alum coagulation lies between 6.0 and 7.5 for turbidity removal, and perhaps between 6.0 and 8.5 with PACl, the efficiency of the coagulation process may be improved with a lower system pH. In addition, the level of "after-floc" formation can be minimized by reducing the system pH to a slightly acidic value. For instance, at a system pH of 6.5, coagulation with alum or PACl would be more effective than at the natural, high raw water pH levels, and the level of after-floc formation and dissolved aluminum residual would be significantly reduced since the solubility concentration of aluminum hydrolysis species at pH 6.5 is only in the order of 0.034 mg/L.

Optimization of the coagulation process therefore, would require provision of an acid feed system - sulphuric or hydrochloric acid - to reduce the natural raw water pH before coagulation, and a lime or caustic soda feed system for final pH adjustment of the treated water. It is expected that at the lower system pH the optimum coagulant dosage for the entire turbidity range encountered at the Lake Huron plant would be lower, flocculation with cold water would be improved, and the potential for after-floc formation reduced. Additional benefits of the lower system pH include improving the overall efficiency of disinfection, and increasing the removal of dissolved natural organic matter by coagulation, which in turn results in lower trihalomethane formation potentials.

In summary, the benefits to be achieved with a lower system pH for treatment are as follows:

- lower consumption of coagulant;
- improve efficiency of coagulation and flocculation with cold water;
- reduce the after-floc formation potential;
- lower the dissolved aluminum residual in the treated water;
- improve the efficiency of the disinfection process;
- reduce trihalomethane formation potential.

As such, it is suggested that investigations be carried out to establish feasibility and cost implications for possible implementation of a coagulation optimization process at the Lake Huron plant.

E.4.4 Stability of Water

The Langelier Saturation Index (LSI) for the raw water varies from about -0.48 in the winter to +0.56 in the summer. For the treated water the LSI was determined as -0.98 in the winter and -0.30 in the summer. The results show that while undergoing treatment, the water becomes slightly aggressive and will in the presence of oxygen corrode metal piping. Water is generally deemed to be non-aggressive if the index is zero or slightly positive.

Tests should be carried out to determine the corrosiveness of the water and the degree to which pH correction using caustic soda should be implemented.

E.4.5 Raw Water Flow Meters

The accuracy of the raw water flow meters is in doubt, and therefore these meters are not used for monitoring the raw water flow.

E.4.6 Low Lift Pumping Station

The existing grit pump (18.9 L/s at 16.8 m TH, 14.9 kW motor) is undersized for use in dewatering the raw water surge well. In the past, a portable submersible pump has been used to assist in dewatering of the well within a reasonable time-frame.

E.4.7 Alum Storage Tanks

Consumption of liquid alum solution is monitored manually by reading a manometer level gauge. This procedure is labour intensive and not as accurate as desirable in establishing daily consumption from which the daily average alum dosage is calculated.

E.4.8 Rotodip Feeders

The Rotodip alum feeders, although in general of robust design and high feed rate accuracy, do not respond quickly to changes in the alum dose rate.

E.4.9 Chlorine Weigh Scale

The existing weigh scale is the mechanical type and only includes a local mechanical dial loss-of-weight indicator. The scale is read each day at mid-night for recording of the daily chlorine gas consumption. Also' with only one scale, individual dosages for pre- and post-chlorination cannot be determined from the total daily loss-of-weight reading.

E.4.10 Filters

As indicated in Sections C.3 and D.4, the existing filter control system is unsuitable for continuous automatic operation of the filters.

E.4.11 Power Supply

The plant has experienced frequent power outages during winter storms which resulted in concerns regarding the reliability of the supply and the plant's capability of maintaining production.

E.4.12 Water Quality Examination

Iron Residual: The purpose for continuing to collect iron residual values should be re-examined.

Aluminum Residual: The test results for aluminum in the treated water appear low in comparison to those obtained at other plants (Metro Toronto). The test procedure used should therefore be reviewed.

Algae: Sampling and analysis for algae in the raw water should be continued.

Organic Substances: Currently no tests are carried out other than those by the Ministry's Drinking Water Surveillance Program.

SECTION F

RECOMMENDATIONS

SECTION F - RECOMMENDATIONS

PART A - SHORT-TERM MODIFICATIONS

F.1. PARTICULATE REMOVAL

1. Primary and Secondary Coagulant Evaluation

Continue jar testing, followed perhaps by additional pilot plant and plant scale testing, to determine best primary coagulant for use in the conventional treatment mode, and with difficult-to-treat water containing colloidal turbidity. Determine the benefits, if any, of secondary coagulants, and define the best order of addition if a combination of chemicals is chosen.

2. Coagulant Dosage Control

Evaluate the use of a feedback controller Streaming Current Detector's output signal can be used to automatically adjust coagulant dose.

3. Optimization of Coagulation process

Carry out studies to establish whether downward adjustments of the raw water pH would be beneficial in the optimization of the performance of the coagulation process. Re-adjustment of treated water pH, of course, would be necessary for stability control.

4. Addition Point of Chemicals

Investigate changing the point of coagulant addition near the hub of the impeller in the rapid mix tanks. Install additional points in both chambers of each reactor if sequencing of the addition of two coagulant chemicals is found to be important.

5. Seasonal Energy Input Adjustment

Investigate adjusting the input energy to the mechanical flocculators from season to season to allow for differences in flow and water temperature.

Also investigate benefits to be achieved from using tapered flocculation with the conventional treatment process.

6. Filter Aid

Determine the benefits of adding a filter aid to the settled water prior to filtration. Investigations could be carried out by pilot or full scale testing.

7. Filter Operation

a) Slow Start-Up

Investigate the effect of a slow start-up of a filter at uniform rate over a 10 to 30-minute period on performance during the filter ripening sequence.

If successful, then it is recommended that this mode of filter start-up operation be included in the impending computerization studies for the Lake Huron plant.

b) Conditioning of Backwash Water

Carry out studies to establish the effectiveness of preconditioning a filter during the backwash using a metal salt or polymer coagulant to reduce the level and duration of increased effluent turbidity during the filter ripening sequence.

c) Filter to Drain

An alternative method for conditioning a filter to improve effluent turbidity during start-up is to filter to drain. The magnitude and duration of the filter ripening sequence should be investigated to determine whether this option is feasible. This procedure could be investigated, at reduced filter rates, using the manually controlled filter drain pipe.

d) Filter Rest Period

Investigate a practice of allowing a backwashed filter to rest at least 15 minutes before reinstatement into service.

The capability of delaying the start-up of a filter after a backwash should be considered during the plant's instrumentation study.

F.2. DISINFECTION

The existing practice at the Lake Huron plant for disinfection of the treated water was found to be very effective in controlling the bacteriological quality of the source water and no modifications are required to be carried out at this time.

F.3. PLANT OPERATIONS

1. Raw Water Flow Meters

The raw water flow meters, including the primary sensing elements, should be flow-tested and re-calibrated so that accurate flow measurements can be made and recorded. In addition, a tracer study should be undertaken to determine the actual flow distribution to the pretreatment units.

2. Low Lift Pumping Station

Install a permanent dewatering pump, adequately sized, in the surge well.

3. Alum Storage Tanks

Provide new sonic level sensing instruments with indicating transmitters for signal transmission to recorders in the Main Control Room.

4. Chlorine Weigh Scale

Replace the existing weigh scale with three new electronic scales, one each for prechlorination and postchlorination service, and one in reserve, complete with electronic instrumentation and signal transmission to the control room.

5. Filters

All filter instrumentation and control systems will be replaced under the upcoming computerization contract.

To permit monitoring filter effluent turbidity from the individual filters, new on-line turbidity meters with recorders should be installed on all filters.

6. Power Supply

Requirements for standby power at the plant should be investigated.

There should be sufficient capacity in emergency power to operate various pumps and auxiliary equipment to sustain the average day plant production at about 160,000 m^3/d.

7. Water Quality Examination

Existing programmes for the examination of raw and treated water quality should be continued. This should include the programme for monthly algae analysis on the raw water.

In addition, the DWSP should be continued whereby the water is examined for many parameters including toxic and potentially toxic organic chemicals which may adversely affect the health of the consumer.

PART B - LONG TERM MODIFICATIONS

F.1. PARTICULATE REMOVAL

1. Plant Hydraulic Distribution Study

Conduct a tracer study to evaluate the distribution of flow to all parallel unit operations, and to determine the extent of short circuiting in each. Determine whether corrective measures need to be taken.

F.2. STABILITY OF WATER

1. Corrosiveness of Plant Effluent

Establish the corrosiveness of the treated water, using such methods as coupon testing, and determine the level of pH adjustment, or any other measures, that need to be implemented in order to control the potential aggressiveness of the treated water.

APPENDIX A

DAILY LOG

Ministry of the Environment
Ontario

LAKE HURON WATER SUPPLY SYSTEM
EQUIPMENT AND OPERATING REPORT

GRAND BEND DATE _____

SHIFT	00:00 to 08:00	08:00 to 16:00	16:00 to 24:00
WEATHER			
LAKE CONDITION			
OUTSIDE TEMPERATURE			
PUMPS OPERATING			
PIPELINE PRESSURE			
PIPELINE FLOW			
ARVA RESERVOIR LEVEL			
ARVA PLANT FLOW			
ARVA RESERVOIR FLOW			
BOOSTER PUMPS OPERATING			
BOOSTER PUMPS PRESS. & FLOW			
HYDRO PEAK			
HYDRO CONSUMPTION X 10,000		XXXXXXXXXXXX	XXXXXXXXXXXX
TIME READINGS TAKEN			
TIME CHARTS DATED		XXXXXXXXXXXX	XXXXXXXXXXXX
SAMPLES TAKEN	XXXXXXXXXXXX		
FILTERS WASHED			
CHLORINE SCALES			
AVE. H.W.T. T.W.T. Cl_2	H	H	H
	T	T	T
	Cl_2	Cl_2	Cl_2
OPERATOR'S SIGNATURE			

LIST – Unusual happenings, equipment failure, repairs required, etc.
(use reverse if necessary)

	URGENT	TIME	OPERATOR

CHECKED BY: CHIEF MAINTENANCE SUPERINTENDENT.

Ministry of the Environment Ontario

Grand Bend

LAKE HURON WATER SUPPLY SYSTEM

FILTER SHEET

DATE _____

Water Temp	RWT		TWT		DOSAGE AL_2		PHR	PHT		Alum Tank	Chlorine Scales	Raw Water

00:00	HRS IN SERVICE	HEAD LOSS	TIME WASHED	HRS	HL	SOUTH POLYMER	DIAL	DOSE	NORTH POLYMER	DIAL	DOSE
1						AL_2			AL_2		
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Cl_2	Feed Rate	Pressure
1		
2		
3		

S.W.T.	
N.S.C.M.	
S.S.C.M.	

Cl_2 Header Pressure _____ AL_2 _____

Cl_2 R F T T

OPERATOR _____

Water Temp	RWT		TWT		DOSAGE AL_2		PHR	PHT		Alum Tank	Chlorine Scales	Raw Water

08:00	HRS IN SERVICE	HEAD LOSS	TIME WASHED	HRS	HL	SOUTH POLYMER O.	DIAL	% DOSE	NORTH POLYMER O.	DIAL	% DOSE
1						AL_2			AL_2		
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Cl_2	Feed Rate	Pressure
1		
2		
3		

S.W.T.	
N.S.C.M.	
S.S.C.M.	

Cl_2 Header Pressure _____ AL_2 _____

Cl_2 R F T T

OPERATOR _____

Water Temp	RWT		TWT		DOSAGE AL_2		PHR	PHT		Alum Tank	Chlorine Scales	Raw Water

16:00	HRS IN SERVICE	HEAD LOSS	TIME WASHED	HRS	HL	SOUTH POLYMER	DIAL	DOSE	NORTH POLYMER	DIAL	DOSE
1						AL_2			AL_2		
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Cl_2	Feed Rate	Pressure
1		
2		
3		

S.W.T.	
N.S.C.M.	
S.S.C.M.	

Cl_2 Header Pressure _____ AL_2 _____

Cl_2 R F T T

OPERATOR _____

APPENDIX B

JAR TEST RESULTS

JAR TEST PROCEDURE

1. Obtain sufficient raw water sample to test for raw water quality (turbidity, pH, temperature, colour, alkalinity) and to fill 6 1.5 L glass jars with exactly 1 L of sample.

2. Place all 6 jars in the gang stirrer and begin mix at 100 rpm. Quickly add the desired amount of primary coagulant to each jar. Add the coagulant to the vortex created by the fast stirring paddles. After coagulant has been added to the last jar, continue rapid mix for 60 seconds, then reduce the paddle speed to 30 rpm.

3. If secondary coagulant is to be used as well, quickly add this in the desired amount to each jar during rapid mix. If the secondary coagulant is a polymer, then this should be added after the addition of primary coagulant. If activated silica is used, then the order of addition should be noted.

4. Continue slow mix at 30 rpm for 30 minutes. After 30 minutes, the paddles should be stopped and removed from the jars.

5. Following the start of the slow mix, observe the time of the first appearance of visible floc in each of the six jars, and also the appearance, size and quantity of floc at the end of the agitation or flocculation period.

6. After 30 minutes of slow mix allow the samples to settle. From a fixed depth of 5 cm, the mid-point of the water depth in the jar, collect samples at 1,2, 4 and 8 minutes after the start of settling and analyse samples for turbidity. Samples drawn at these times represent settling velocities of 5, 2.5, 1.25 and 0.625 cm/min. respectively. Plot the results in terms of settling velocity distribution curves.

7. Following the settling period, pipette 200 mL of supernatant from each jar. Use 50 mL to wet a glass fibre filter disc and discard. Filter the remaining sample and measure the turbidity of the finished water. Use a separate filter apparatus and filter disk for each sample from each jar. Use Gelman Sciences Type A/E 47 mm glass fibre filters or Whatman No. 40 filter discs.

GRAND BEND WATER TREATMENT PLANT

JAR TEST NUMBER: 1

JAR TEST RESULTS

DATE SAMPLED: MARCH 10,1988

RAW WATER CHARACTERISTICS

TURBIDITY : 1.17 NTU
COLOUR : 10 ACU
TEMPERATURE : 2.1 C
pH : 7.94

JAR NUMBER	COAGULANT and DOSE (mg/L)	FLOC CHARACTERISTICS: Time to 1st floc	Appearance	Size	Quantity	SETTLED WATER SAMPLES: Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)	FILTERED WATER SAMPLES Turbidity (NTU)
1	Alum 4	1 min	very small pin floc; floc do not grow in size during 30 min of flocculation	<1 mm	1	1:40	1.7	2:40	1.6	4:40	1.4	10:40	1.5	0.18
2	Alum 8	<1 min	pin floc	<1 mm	2	1:30	1.9	2:30	1.6	4:30	1.2	10:30	1.2	0.08
3	Alum 12	flash	small floc; particles are loosely bound, not very dense; spherical shape	1 mm	3	1:20	2.1	2:20	1.6	4:20	1.2	10:20	0.7	0.09
4	Alum 16	flash	same characteristics as jar no. 3, except floc are slightly larger; not very strong	2 mm	3	1:10	4.8	2:10	4.2	4:10	1.4	10:10	0.4	0.10
5	Alum 20	flash	same characteristics as jar no. 4, except floc are more numerous	2 mm	4	1:00	2.7	2:00	3.3	4:00	1.8	10:00	0.9	0.04
6	Alum 24	flash	same characteristics as jar no. 4, except floc are more numerous; spherical in shape; not very dense or strong	2 mm	4	0:50	2.9	1:50	3.0	3:50	1.9	9:50	0.3	0.06

GRAND BEND WATER TREATMENT PLANT

JAR TEST NUMBER: 2

RAW WATER CHARACTERISTICS

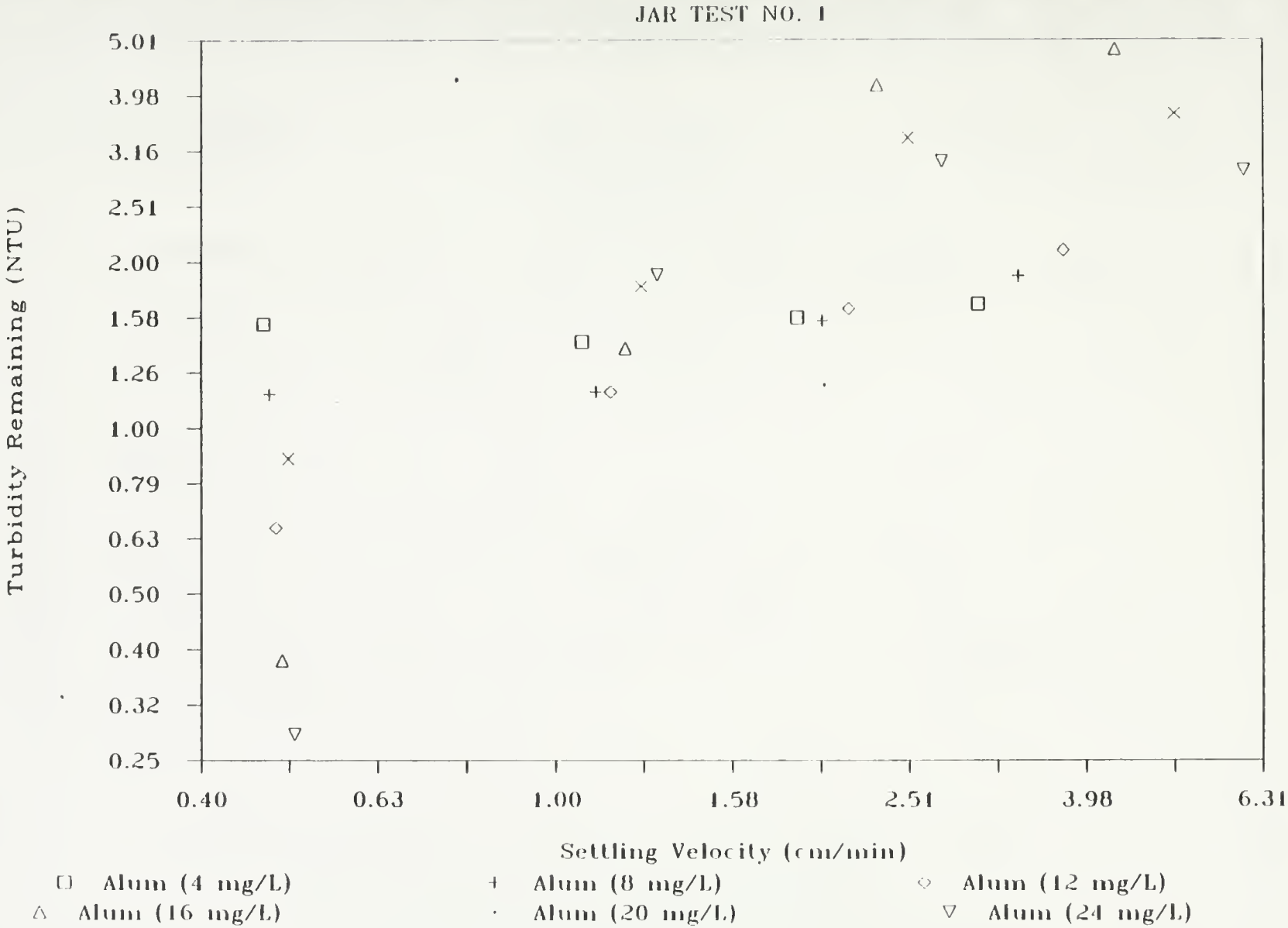
JAR TEST RESULTS

DATE SAMPLED: MARCH 10,1989

TURBIDITY : 1.17 NTU
COLOUR : 10 ACU
TEMPERATURE : 2.2 C
pH : 7.96

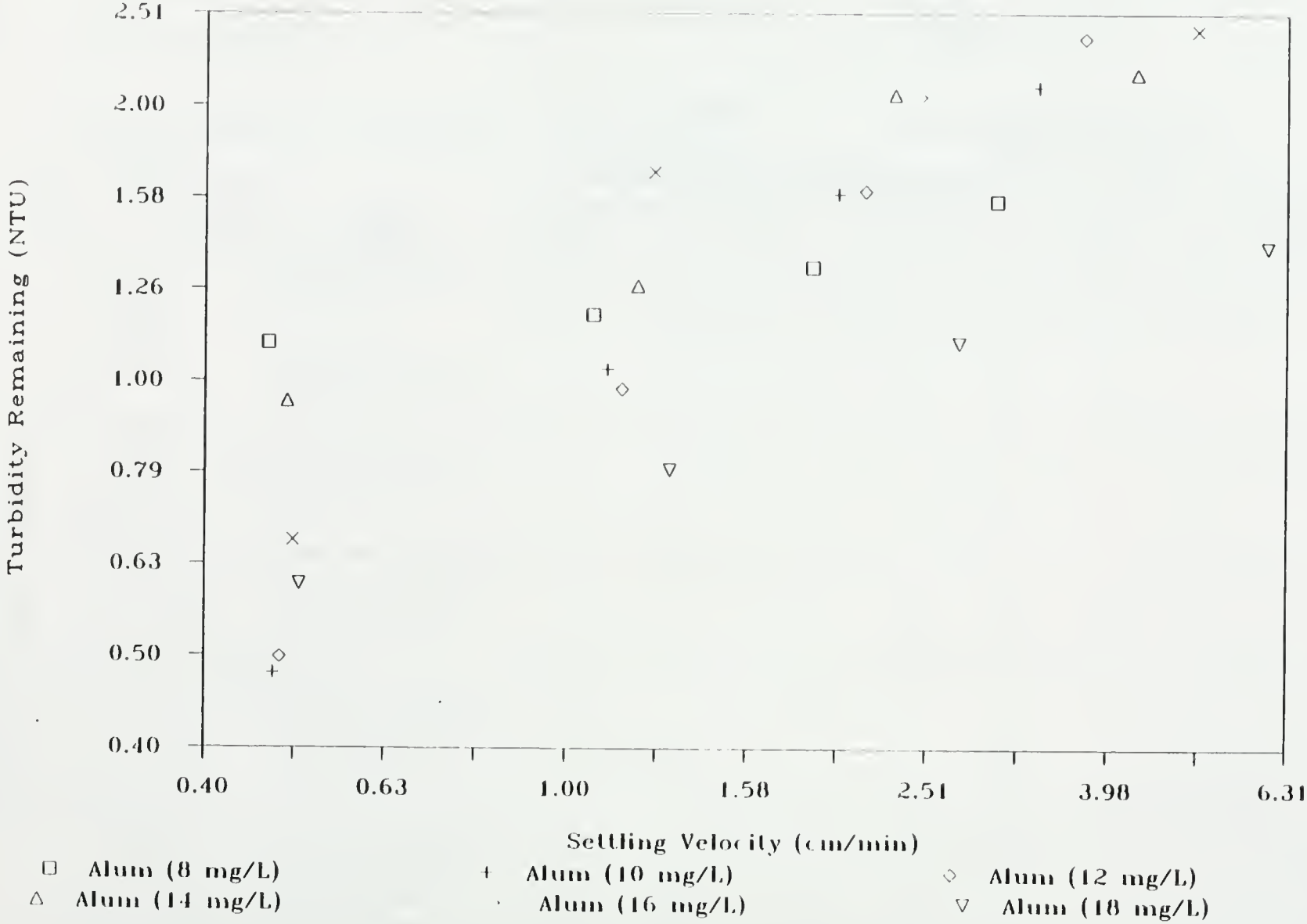
JAR NUMBER	COAGULANT and DOSE (mg/L)	FLOC CHARACTERISTICS: Time to 1st floc	Appearance	Size	Quantity	SETTLED WATER SAMPLES: Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)	Time (min:sec)	Turbidity (NTU)
1	Alum 8	1 min	pin floc: structure not dense	<1 mm	2	1:40	1.6	2:40	1.3	4:40	1.2	10:40	1.1
2	Alum 10	1 min	small floc; particles are loosely bound, not very dense; spherical shape	1 mm	2	1:30	2.1	2:30	1.6	4:30	1.0	10:30	0.5
3	Alum 12	<1 min	same characteristics as jar no. 2, except floc are more numerous	1 mm	3	1:20	2.4	2:20	1.6	4:20	1.0	10:20	0.5
4	Alum 14	flash	same characteristics as jar no. 3, except floc are slightly larger; not very strong	2 mm	3	1:10	2.4	2:10	2.0	4:10	1.4	10:10	0.5
5	Alum 16	flash	same characteristics as jar no. 3, except floc are slightly larger; spherical shape; not very strong	2 mm	4	1:00	2.2	2:00	2.0	4:00	1.3	10:00	1.0
6	Alum 18	flash	same characteristics as jar no. 3, except floc are slightly larger; spherical shape; not very strong .	2 mm	4	0:50	2.4	1:50	2.0	3:50	1.7	9:50	0.7

SETTLING VELOCITY DISTRIBUTION CURVE



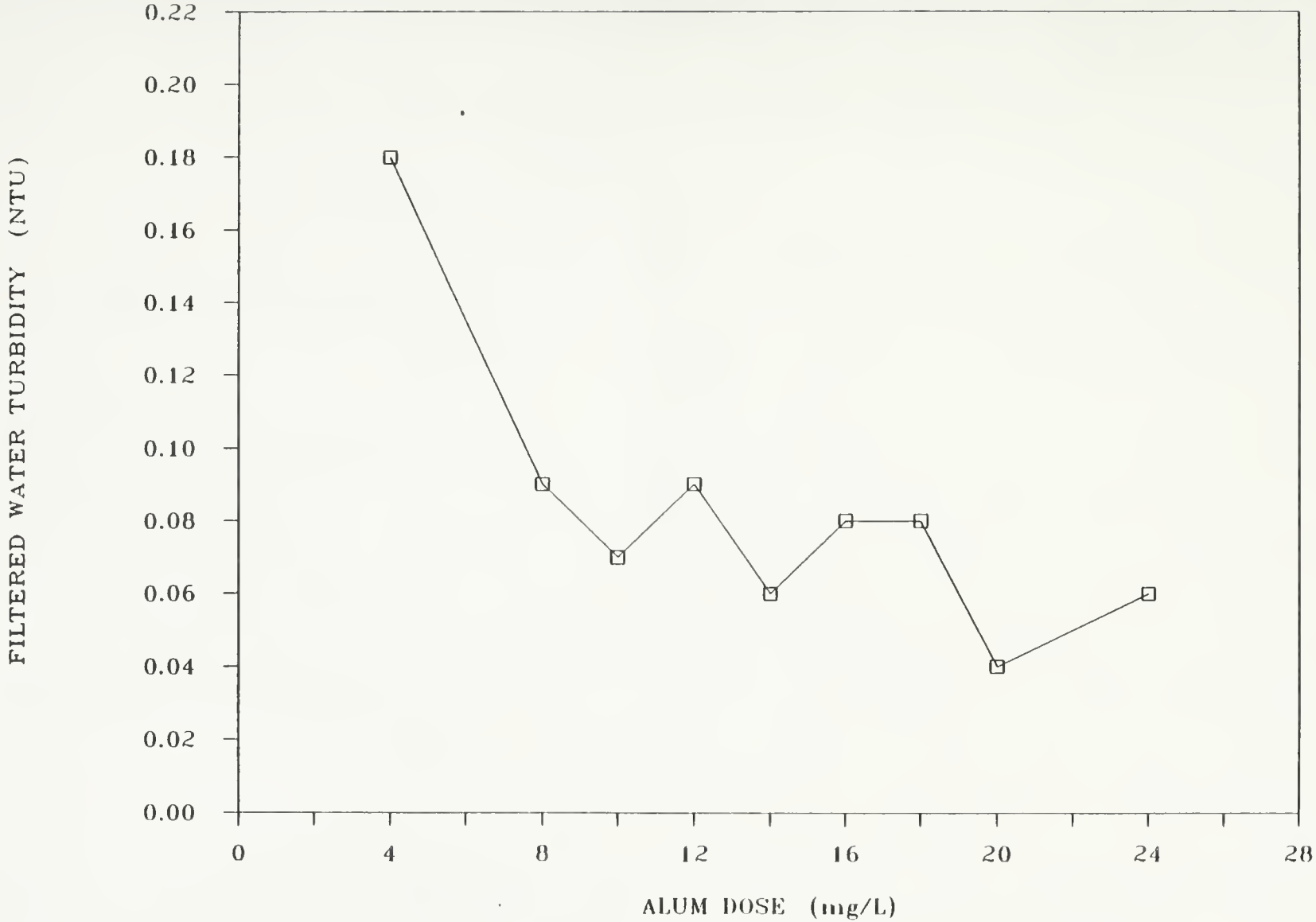
SETTLING VELOCITY DISTRIBUTION CURVE

JAR TEST NO. 2



FILTERED WATER TURBIDITY vs ALUM DOSE

Results of Jar Tests 1 and 2



APPENDIX C

TABLES OF OPERATING RECORD

TABLE 1

WATER PLANT OPTIMIZATION STUDY
"PLANT FLOWS"

06/04/87 (REV. 1)

TABLE 1.0: FLOWS (ML/d)

WPOS - Lake Huron Water Supply System

MONTH	R/T	1987			1986			1985					
		MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.
JAN	R	171.44	114.71	139.61	181.12	112.56	143.40	158.7	92.5	144.5			
	T	168.5	112.6	136.8	175.9	111.0	138.5	146.6	90.3	137.5			
FEB	R	168.41	79.77	145.59	166.93	79.02	144.48	178.4	137.3	152.7			
	T	165.8	77.3	142.8	163.1	76.1	139.7	175.1	134.9	148.5			
MAR	R	160.03	139.61	151.58	169.18	127.18	151.93	159.7	123.9	137.6			
	T	157.0	137.6	148.9	159.2	122.1	144.7	151.4	118.7	127.9			
APR	R	192.76	141.55	151.49	170.13	126.19	153.96	175.0	112.6	146.6			
	T	193.13	140.24	150.3	155.8	121.5	143.8	169.9	107.9	137.4			
MAY	R	273.23	137.25	177.57	213.59	125.80	154.99	205.8	129.4	158.7			
	T	267.43	134.55	174.3	198.3	116.5	143.3	196.6	120.3	148.9			
JUN	R	262.41	174.37	217.05	209.27	160.16	181.90	225.8	129.8	175.7			
	T	259.31	170.17	213.11	198.5	151.9	174.6	204.3	125.4	164.4			
JUL	R	357.09	178.57	227.04	249.39	151.84	190.45	227.5	151.4	189.4			
	T	346.71	175.12	221.12	240.3	141.5	180.8	219.3	146.7	181.7			
AUG	R	272.43	144.26	199.93	208.42	140.45	169.01	205.8	135.5	167.4			
	T	267.83	137.06	194.82	204.4	133.3	161.6	199.0	130.0	161.7			
SEP	R	235.53	117.89	180.26	209.06	165.05	185.98	202.6	136.1	162.6			
	T	231.73	116.62	176.70	198.0	160.9	177.3	193.4	136.1	156.6			
OCT	R	207.83	128.85	159.31	197.57	137.44	163.78	163.7	119.6	146.5			
	T	204.63	125.85	156.15	185.8	131.5	158.8	156.5	115.1	142.4			
NOV	R	196.44	133.18	163.16	174.63	135.30	157.73	157.53	115.13	138.02			
	T	194.14	130.18	160.26	161.8	133.3	154.7	153.7	112.6	138.0			
DEC	R	177.80	112.95	147.50	158.11	110.70	138.85	171.73	118.51	144.63			
	T	175.50	110.15	144.84	155.2	108.9	135.7	150.2	120.1	137.8			

R = Raw; T = Treated

TABLE 1.1: PER CAPITA CONSUMPTION
(L/d/Capita)

WPOS - Lake Huron Water Supply System

CONSUMPTION	1987	1986	1985	
Population (1)	298,100	295,700	291,000	
Maximum Day	1,163	813	754	
Minimum Day	259	257	310	
Average Day	565	514	511	
Ratio MD:AD	2.06	1.56	1.48	

(1) Entire population served by the Lake Huron Water Supply System.

TABLE 2

WATER PLANT OPTIMIZATION STUDY
"PARTICULATE REMOVAL SUMMARY"

06/04/87 (REV. 1)

TABLE 2.0: PARTICULATE REMOVAL SUMMARY

WPOS - Lake Huron Water Supply System

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
JAN	Turbidity (FTU)	R	31.2	1.7	8.6	17.7	1.5	4.9	25.4	3.0	11.2			
		T	0.16	0.05	0.09	0.31	0.14	0.23	0.36	0.08	0.21			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		20.0	8.2	11.8/31	13.9	8.9	10.8/11	19.9	8.9	12.6/27			
	- Ferric Chloride (mg/L)					4	2	3/20	4	4	4/11			
	- PACl (mg/L)													
	Filter Aid (1)(2) (mg/L)					0.012	0.010	0.011/3	0.06	0.01	0.05/13			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.07	0.02	0.03	0.05	0.01	0.03	0.06	0.04	0.05			
	Metal Res. Fe (mg/L)	R												
		T	0.05	0.00	0.01	0.06	0.00	0.02	0.08	0.01	0.03			
	pH	R	8.14	7.76	7.94	8.02	7.30	7.70	8.16	7.58	7.86			
		T	7.77	7.37	7.59	7.72	7.07	7.37	7.87	7.34	7.58			
	Temperature (°C)		6	3	4	6	3	4	5	3	4			
FEB	Turbidity (FTU)	R	107.8	6.5	20.5	4.2	1.2	2.3	21.1	1.0	3.0			
		T	0.19	0.06	0.11	0.31	0.11	0.19	0.74	0.15	0.26			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		23.8	1.5	16.7/28	15.0	6.5	10.2/24	33.0	28.4	30.7/2			
	- Ferric Chloride (mg/L)					4	2	4/6	8	4	4.7/28			
	- PACl (mg/L)													
	Filter Aid (1)(2) (mg/L)					0.030	0.009	0.020/8	0.04	0.04	0.04/2			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.06	0.01	0.03	0.07	0.02	0.04	0.06	0.02	0.04			
	Metal Res. Fe (mg/L)	R												
		T	0.04	0.00	0.01	0.09	0.00	0.02	0.07	0.01	0.03			
	pH	R	8.80	7.75	8.05	8.23	7.21	7.74	8.20	7.68	7.95			
		T	7.87	7.51	7.67	7.83	7.11	7.48	7.99	7.45	7.74			
	Temperature (°C)		6	3	4	4	3	4	5	3	3			

R = Raw; T = Treated (1) Dose/No. of Days Applied

(2) 1986 - Drew 6306A

1985 - Separan NP10

TABLE 2.0 (cont'd.)

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
MAR	Turbidity (FTU)	R	60.3	5.9	21.7	22.1	0.9	5.1	37.0	5.0	14.7			
		T	0.15	0.06	0.10	0.24	0.07	0.13	0.68	0.08	0.23			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		26.9	14.9	21.7/31	29.6	7.1	12.8/31	45.1	10.2	19.3/30			
	- Ferric Chloride (mg/L)							4/1	10	4	8/7			
	- PACl (mg/L)					4.0	3.5	3.7/12						
	Filter Aid (1)(2) (mg/L)					0.050	0.002	0.022/16	0.08	0.002	0.05/22			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.06	0.00	0.03	0.07	0.01	0.03			0.00			
	Metal Res. Fe (mg/L)	R												
		T	0.05	0.00	0.01	0.04	0.01	0.02	0.07	0.01	0.03			
	pH	R	8.47	7.92	8.16	8.2	7.0	7.7	8.11	6.96	7.73			
		T	7.93	7.39	7.71	7.93	6.87	7.44	8.04	6.72	7.51			
	Temperature (°C)		7	3	4	6	3	4	5	3	5			
APR	Turbidity (FTU)	R	60.0	1.8	14.1	22.5	1.8	7.1	31.7	2.6	16.0			
		T	0.13	0.06	0.09	0.23	0.09	0.14	0.33	0.07	0.19			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		27.7	11.5	19.7/30	24.7	8.4	16.2/30	25.5	8.3	15.6/30			
	- Ferric Chloride (mg/L)													
	- PACl (mg/L)													
	Filter Aid (1)(2)(3) (mg/L)					0.03	0.02	0.02/16	0.060	0.003	0.011/18			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.08	0.00	0.04	0.08	0.01	0.04	0.14	0.02	0.08			
	Metal Res. Fe (mg/L)	R												
		T	0.05	0.00	0.01	0.04	0.01	0.02	0.07	0.00	0.03			
	pH	R	8.55	7.76	8.27	8.04	7.23	7.74	8.19	7.24	7.54			
		T	7.98	7.44	7.74	7.72	6.97	7.39	8.09	7.07	7.35			
	Temperature (°C)		12	6	8	9	5	7	9	5	7			

R = Raw; T = Treated (1) Dose/No. of Days Applied

(2) March 1 to 22, 1985 - Separan NP10
March 23, 1985 to October 27, 1986 - Drew 6306A

(3) Drew 6306A

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
MAY	Turbidity (FTU)	R	16.1	1.8	5.4	30.5	3.4	9.0	12.1	2.9	6.4			
		T	0.21	0.09	0.13	0.37	0.17	0.22	0.51	0.11	0.26			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		26.3	12.7	19.2/31	35.2	6.7	21.4/31	18.6	9.6	13.4/30			
	- Ferric Chloride (mg/L)								7	6	7/2			
	- PACl (mg/L)					6.0	6.0	6.0/5						
	Filter Aid (1)(3) (mg/L)					0.030	0.1	0.021/31	0.011	0.001	.006/13			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.13	0.01	0.05	0.09	0.01	0.04	0.12	0.03	0.08			
	Metal Res. Fe (mg/L)	R												
		T	0.18	0.00	0.02	0.04	0.00	0.01	0.04	0.01	0.02			
	pH	R	8.76	8.23	8.47	7.55	8.30	7.95	8.19	7.45	7.84			
		T	8.06	7.72	7.86	7.93	7.23	7.50	8.00	7.19	7.61			
	Temperature (°C)		14	10	12	13	9	10	14	9	11			
JUN	Turbidity (FTU)	R	3.7	1.1	2.0	9.7	1.3	4.3	14.6	1.0	3.7			
		T	0.31	0.10	0.18	0.32	0.15	0.23	0.61	0.18	0.30			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		26.6	11.6	19.1/30	21.3	11.5	16.8/30	15.6	8.9	12.0/17			
	- Ferric Chloride (mg/L)								4	3	4/14			
	- PACl (mg/L)													
	Filter Aid (1)(3) (mg/L)					0.020	0.01	0.017/15			0.009/1			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.17	0.01	0.08	0.17	0.02	0.07	0.12	0.05	0.09			
	Metal Res. Fe (mg/L)	R												
		T	0.03	0.01	0.02	0.03	0.00	0.01	0.03	0.01	0.02			
	pH	R	8.86	8.14	8.73	8.14	7.48	7.91	8.28	7.57	7.81			
		T	8.03	7.70	7.89	7.81	7.13	7.55	7.96	7.23	7.51			
	Temperature (°C)		20	12	15	18	10	14	17	10	14			

R = Raw; T = Treated (1) Dose/No. of Days Applied

(3) Drew 6306A

TABLE 2.0 (cont'd.)

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
JUL	Turbidity (FTU)	R	8.7	1.1	3.1	4.3	2.2	3.1	13.9	1.3	4.3			
		T	0.26	0.09	0.15	0.34	0.18	0.24	0.40	0.17	0.28			
	Colour (TCU)	R												
		T												
	Coagulant (1) Alum (mg/L)		28.1	10.4	17.2/31	19.3	12.0	15.4/16	16.3	8.8	11.8/15			
	- Ferric Chloride (mg/L)					9	5	8/21	10	4	6/16			
	- PACl (mg/L)													
	Filter Aid (1)(3) (mg/L)					0.03	0.01	0.02/20						
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.21	0.04	0.12	0.13	0.01	0.09						
	Metal Res. Fe (mg/L)	R												
		T	0.02	0.01	0.01	0.12	0.00	0.03	0.06	0.01	0.02			
	pH	R	8.85	8.62	8.71	8.40	7.61	8.13	7.98	7.57	7.80			
		T	8.06	7.49	7.93	7.98	7.40	7.74	7.74	7.21	7.48			
	Temperature (°C)		24	15	21	21	14	17	21	14	18			
AUG	Turbidity (FTU)	R	49.0	1.8	9.4	41.3	1.0	7.6	5.1	1.4	2.5			
		T	0.24	0.13	0.18	0.27	0.13	0.20	0.68	0.18	0.30			
	Colour (TCU)	R												
		T												
	Coagulant (1) Alum (mg/L)		27.7	12.3	20.9	22.4	14.0	19.2/8	16.1	9.1	13.2/7			
	- Ferric Chloride (mg/L)					10	2	4/31	6	3	4/24			
	- PACl (mg/L)								4.0	1.5	2.9/3			
	Filter Aid (mg/L)													
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.18	0.05	0.11	0.12	0.01	0.05	0.08	0.05	0.07			
	Metal Res. Fe (mg/L)	R												
		T	0.04	0.01	0.01	0.04	0.01	0.02	0.03	0.01	0.01			
	pH	R	8.84	8.49	8.70	8.31	7.82	8.09	8.44	7.75	8.21			
		T	8.11	7.75	7.95	7.99	7.45	7.76	7.99	7.37	7.71			
	Temperature (°C)		22	15	20	23	20	22	22	15	19			

R = Raw; T = Treated (1) Dose/No. of Days Applied
(3) Drew 6306A

TABLE 2.0 (cont'd.)

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
SEP	Turbidity (FTU)	R	25.9	2.0	7.2	73.5	2.2	11.6	7.6	1.0	2.5			
		T	0.30	0.10	0.16	0.56	0.12	0.25	0.40	0.17	0.28			
	Colour (TCU)	R												
		T												
	Coagulant (1) Alum (mg/L)		29.3	11.6	19.5	31.0	8.9	20.8/30						
	- Ferric Chloride (mg/L)					7	4	6/12	4	2	3/25			
	- PACl (mg/L)								4.0	2.0	2.7/6			
	Filter Aid (1)(3) (mg/L)					0.05	0.02	0.03/18						
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.15	0.04	0.08	0.16	0.04	0.10	0.23	0.01	0.06			
	Metal Res. Fe (mg/L)	R												
		T	0.03	0.01	0.01	0.06	0.01	0.02	0.05	0.00	0.02			
	pH	R	8.81	7.63	8.41	8.43	7.64	7.96	8.26	7.74	8.08			
		T	8.12	7.36	7.75	7.99	7.41	7.65	7.93	7.48	7.73			
	Temperature (^{o}C)		20	17	19	21	17	19	22	13	19			
OCT	Turbidity (FTU)	R	33.3	1.6	11.7	139.6	2.2	21.3	12.4	1.1	2.9			
		T	0.25	0.09	0.14	0.70	0.08	0.21	0.38	0.15	0.22			
	Colour (TCU)	R												
		T												
	Coagulant (1) Alum (mg/L)		23.1	9.4	16.8	34.1	13.7	22.7/31						
	- Ferric Chloride (mg/L)					8	4	6/8	6	2	3/31			
	- PACl (mg/L)													
	Filter Aid (1)(3) (mg/L)					0.03	0.02	0.03/13						
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.16	0.03	0.08	0.09	0.03	0.06	0.06	0.01	0.02			
	Metal Res. Fe (mg/L)	R												
		T	0.08	0.01	0.02	0.05	0.00	0.02	0.06	0.01	0.03			
	pH	R	8.25	7.83	8.06	8.27	7.37	7.76	8.22	7.69	7.98			
		T	7.80	7.33	7.56	7.98	7.28	7.62	7.87	7.45	7.71			
	Temperature (^{o}C)		19	11	14	19	13	15	18	14	15			

R = Raw; T = Treated (1) Dose/No. of Days Applied

(3) Drew 6306A

TABLE 2.0 (cont'd.)

MONTH	PARAMETER		1987 MAX.	1987 MIN.	1987 AVG.	1986 MAX.	1986 MIN.	1986 AVG.	1985 MAX.	1985 MIN.	1985 AVG.	MAX.	MIN.	AVG.
NOV	Turbidity (FTU)	R	70.8	1.8	14.9	53.3	1.5	8.9	21.1	2.1	8.1			
		T	0.27	0.12	0.16	0.23	0.08	0.14	0.44	0.15	0.27			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		20.1	10.6	15.1	27.3	6.0	13.0/30	14.8	10.0	12.4/2			
	- Ferric Chloride (mg/L)					8	4	6/3	8	3	5/16			
	- PACl (mg/L)								6.0	1.0	3.4/17			
	Filter Aid (1)(3) (mg/L)								0.02	0.01	0.02/2			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.16	0.02	0.06	0.17	0.01	0.05	0.08	0.01	0.04			
	Metal Res. Fe (mg/L)	R												
		T	0.02	0.01	0.01	0.04	0.01	0.02	0.07	0.00	0.01			
	pH	R	8.36	7.62	7.94	8.10	7.35	7.74	7.73	8.45	8.02			
		T	7.68	7.11	7.39	7.90	7.27	7.57	8.06	7.31	7.64			
	Temperature (°C)		11	7	9	13	8	10	12	8	11			
DEC	Turbidity (FTU)	R	68.8	8.2	20.9	10.9	1.9	5.4	92.5	3.9	19.0			
		T	0.24	0.06	0.13	0.13	0.06	0.10	0.82	0.13	0.24			
	Colour (TCU)	R												
		T												
	Coagulant (1) - Alum (mg/L)		26.4	11.8	17.4	12.7	5.4	9.2/31	12.2	8.7	10.0/3			
	- Ferric Chloride (mg/L)								3	3	3/3			
	- PACl (mg/L)								6.0	2.0	3.3/29			
	Filter Aid (1)(3) (mg/L)								0.028	0.006	0.015/10			
	Metal Res. Al (mg/L)	R												
	(mg/L)	T	0.20	0.01	0.04	0.11	0.02	0.04	0.22	0.02	0.06			
	Metal Res. Al/Fe (mg/L)	R												
		T	0.03	0.01	0.01	0.03	0.01	0.01	0.08	0.00	0.02			
	pH	R	8.39	7.37	8.08	8.24	7.4	7.86	8.36	7.39	7.89			
		T	7.92	6.97	7.50	7.67	7.22	7.51	8.07	7.18	7.69			
	Temperature (°C)		7	4	5	8	5	6	9	3	6			

R = Raw; T = Treated (1) Dose/No. of Days Applied

(3) Drew 6306A

TABLE 2.1 PARTICULATE REMOVAL PROFILE

JANUARY 1987

WPOS - Lake Huron Water Supply System

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	$FeCl_3$	PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	1.9			0.07			8.5					0.03		0.01	7.95	7.57	6
2	1.7			0.08			9.1					0.02		0.01	7.99	7.58	6
3	3.9			0.10			8.8					0.07		0.01	8.07	7.77	6
4	3.8			0.16			11.5					0.04		0.01	8.09	7.74	6
5	3.3			0.12			10.6					0.04		0.02	7.99	7.68	5
6	2.6			0.07			10.4					0.03		0.01	7.88	7.55	5
7	6.1			0.12			10.5					0.03		0.00	7.78	7.57	5
8	11.5			0.06			10.0					0.06		0.01	7.76	7.48	5
9	10.0			0.07			10.7					0.03		0.01	8.05	7.75	5
10	4.5			0.08			8.2					0.04		0.01	7.91	7.59	4
11	8.0			0.08			8.7					0.03		0.01	7.92	7.63	4
12	10.2			0.07			9.7					0.07		0.01	7.84	7.48	5
13	7.1			0.07			9.8					0.04		0.01	7.96	7.61	5
14	4.0			0.08			9.3					0.03		0.01	7.85	7.59	4
15	5.0			0.11			9.2					0.04		0.02	7.94	7.59	4

TABLE 2.1(cont'd.)

JANUARY 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	10.2	2.3		0.13			10.7					0.06		0.01	7.98	7.62	4
17	6.8	2.3		0.13			11.0					0.03		0.05	7.90	7.59	5
18	6.8	2.3		0.12			11.0					0.03		0.01	7.87	7.60	4
19	11.5	3.2		0.10			12.8					0.02		0.03	8.04	7.73	3
20	14.2	3.5		0.09			16.3					0.03		0.03	7.92	7.61	3
21	9.9	2.2		0.08			19.1					0.04		0.02	7.95	7.57	4
22	7.8	1.7		0.09			19.5					0.02		0.02	8.14	7.77	4
23	31.2	2.1		0.09			18.0					0.03		0.02	7.95	7.55	4
24	26.5	2.3		0.11			20.0					0.03		0.01	7.89	7.41	3
25	15.1	1.6		0.12			15.0					0.03		0.02	7.85	7.57	4
26	6.1	1.8		0.12			12.0					0.02		0.01	7.88	7.37	3
27	4.4	1.4		0.09			11.6					0.03		0.00	7.90	7.54	4
28	3.6	1.2		0.05			11.1					0.03		0.01	8.06	7.68	3
29	7.1	1.7		0.07			9.6					0.03		0.02	7.96	7.48	4
30	4.6	1.8		0.08			10.3					0.03		0.01	7.94	7.54	3
31	16.3	2.0		0.10			12.8					0.02		0.00	7.90	7.60	3

TABLE 2.1 PARTICULATE REMOVAL PROFILE APRIL 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT $FeCl_3$	PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	30.5	2.2		0.08			26.6					0.00		0.01	8.15	7.72	6
2	25.2	1.8		0.07			24.7					0.02		0.05	7.92	7.48	6
3	60.0	1.6		0.06			20.2					0.05		0.01	8.13	7.44	6
4	49.8	3.0		0.10			15.4					0.02		0.01	8.00	7.57	6
5	43.0	2.5		0.10			21.8					0.05		0.03	7.76	7.61	6
6	37.7	2.9		0.11			27.7					0.06		0.02	8.19	7.69	6
7	22.1	2.2		0.06			21.3					0.04		0.01	8.16	7.58	7
8	14.7	2.5		0.07			19.5					0.02		0.01	8.30	7.74	6
9	7.5	1.8		0.06			14.4					0.03		0.01	8.14	7.62	6
10	4.7	2.3		0.08			12.8					0.02		0.00	8.10	7.73	6
11	7.4	2.4		0.13			18.8					0.04		0.01	8.17	7.64	7
12	6.3	2.2		0.11			23.4					0.02		0.01	8.19	7.77	7
13	6.6	2.1		0.09			24.9					0.01		0.01	8.24	7.83	7
14	6.4	2.9		0.12			26.5					0.07		0.03	8.34	7.74	8
15	5.1	1.9		0.10			22.7					0.07		0.00	8.34	7.83	8

TABLE 2.1(cont'd.)

APRIL 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	4.3	1.5		0.08			21.1					0.03		0.00	8.27	7.69	7
17	2.9	1.3		0.09			15.4					0.05		0.01	8.36	7.65	8
18	1.9	1.3		0.08			11.5					0.04		0.01	8.24	7.75	8
19	2.0	1.5		0.09			13.0					0.03		0.01	8.21	7.76	7
20	1.8	1.7		0.11			14.2					0.04		0.01	8.33	7.87	8
21	2.5	1.7		0.11			15.5					0.05		0.01	8.53	7.98	9
22	13.5	2.0		0.13			21.1					0.07		0.04	8.55	7.92	10
23	10.6	1.7		0.07			16.3					0.06		0.00	8.53	7.87	10
24	6.3	1.9		0.12			21.3					0.08		0.02	8.46	7.87	12
25	6.5	1.9		0.10			23.1					0.06		0.01	8.33	7.79	12
26	1.9	1.7		0.09			19.0					0.08		0.02	8.35	7.75	11
27	2.7	1.7		0.09			18.8					0.08		0.01	8.42	7.90	11
28	8.1	1.5		0.06			19.9					0.03		0.01	8.45	7.74	11
29	8.7	1.5		0.07			18.5					0.04		0.01	8.35	7.74	11
30	23.3	2.1		0.11			20.4					0.03		0.00	8.45	7.85	11
31																	

TABLE 2.1 PARTICULATE REMOVAL PROFILE JULY 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT $FeCl_3$	COAGULANT PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	1.4	1.5		0.16			18.5					0.11		0.01	8.65	7.97	20
2	3.5	2.3		0.20			18.6					0.13		0.01	8.78	7.92	19
3	5.2	2.2		0.12			20.3					0.10		0.01	8.64	7.49	16
4	6.1	1.2		0.14			24.2					0.10		0.01	8.72	7.76	15
5	5.7	1.3		0.22			27.1					0.04		0.01	8.63	7.87	15
6	5.2	1.6		0.26			28.1					0.05		0.02	8.78	7.82	17
7	3.5	1.9		0.23			26.0					0.11		0.02	8.77	7.97	17
8	2.8	1.9		0.13			18.2					0.09		0.01	8.65	7.83	19
9	2.1	1.8		0.13			14.8					0.08		0.01	8.64	7.91	20
10	1.4	1.6		0.12			15.1					0.10		0.01	8.70	7.95	21
11	1.1	1.3		0.09			15.0					0.12		0.02	8.75	7.90	23
12	1.1	1.4		0.09			11.7					0.15		0.02	8.73	7.81	23
13	1.1	1.4		0.10			10.8					0.18		0.01	8.62	8.00	24
14	8.3	2.0		0.18			16.1					0.13		0.01	8.64	8.01	23
15	8.7	1.9		0.17			20.8					0.08		0.02	8.64	7.98	21

TABLE 2.1(cont'd.)

JULY 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	4.2	1.7		0.17			22.2					0.08		0.02	8.63	7.98	20
17	4.0	1.7		0.15			20.9					0.13		0.02	8.65	7.94	20
18	2.1	1.7		0.13			20.9					0.16		0.02	8.78	8.02	22
19	2.4	1.5		0.13			19.1					0.18		0.01	8.69	8.01	22
20	1.7	1.4		0.11			18.6					0.16		0.01	8.85	7.94	22
21	2.3	1.5		0.12			10.4					0.10		0.02	8.84	7.99	23
22	1.3			0.12			10.9					0.09		0.01	8.77	7.97	23
23	1.2			0.11			11.3					0.13		0.01	8.68	7.86	22
24	1.5			0.09			11.6					0.15		0.01	8.72	7.98	23
25	1.5			0.11			11.4					0.21		0.01	8.74	8.01	24
26	1.5			0.10			10.6					0.16		0.01	8.77	8.00	24
27	2.8			0.17			10.8					0.15		0.02	8.76	8.06	21
28	3.4			0.22			16.0					0.17		0.01	8.64	7.95	20
29	3.6			0.22			15.5					0.12		0.01	8.65	8.03	21
30	3.1			0.19			19.0					0.15		0.01	8.78	7.96	22
31	3.5			0.17			18.7					0.13		0.02	8.80	7.96	22

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT $FeCl_3$	COAGULANT PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	21.5	1.8		0.14			19.9					0.16		0.02	8.20	7.50	19
2	17.3	1.5		0.12			19.0					0.06		0.01	8.07	7.44	19
3	47.0	1.7		0.16			22.2					0.05		0.01	8.21	7.45	17
4	17.1	1.6		0.13			23.1					0.08		0.01	8.17	7.49	17
5	11.4	2.0		0.17			20.8					0.06		0.01	8.12	7.51	17
6	10.9	1.9		0.15			18.3					0.09		0.01	8.11	7.46	15
7	12.8	1.9		0.16			16.6					0.10		0.03	8.06	7.55	15
8	33.3	1.6		0.12			18.1					0.04		0.02	8.03	7.46	15
9	29.7	2.3		0.13			17.3					0.06		0.01	8.05	7.50	14
10	22.0	2.1		0.13			18.9					0.07		0.01	8.14	7.53	14
11	12.2	1.9		0.12			18.2					0.09		0.02	8.00	7.53	13
12	13.9	2.1		0.15			19.7					0.04		0.01	7.99	7.49	13
13	8.4	1.7		0.12			18.7					0.06		0.01	7.98	7.50	13
14	5.1	1.9		0.12			20.3					0.04		0.02	8.16	7.58	14
15	4.4	1.8		0.09			17.9					0.03		0.01	8.11	7.53	13

TABLE 2.1(cont'd.)

OCTOBER 1987

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	3.2	1.7		0.11			14.5					0.15		0.02	8.19	7.70	13
17	3.0	1.6		0.12			14.2					0.08		0.08	8.25	7.68	14
18	7.3	1.7		0.13			14.2					0.08		0.03	8.04	7.66	13
19	2.9	1.7		0.12			14.4					0.06		0.01	8.05	7.66	13
20	2.6	1.5		0.09			14.3					0.11		0.02	8.04	7.58	13
21	2.1	1.7		0.11			9.4					0.07		0.02	8.00	7.63	14
22	1.6	1.8		0.15			9.8					0.12		0.02	7.95	7.68	14
23	2.0	2.1		0.16			11.2					0.09		0.02	8.14	8.07	13
24	2.4	1.9		0.16			12.3					0.09		0.01	8.18	7.80	12
25	21.3	2.9		0.23			17.9								7.83	7.33	12
26	9.8	2.2		0.15			21.1					0.08		0.02	7.96	7.47	11
27	6.9	2.2		0.17			18.9					0.09		0.02	7.98	7.54	12
28	12.0	2.3		0.15			19.1					0.06		0.01	8.00	7.43	12
29	8.1	1.9		0.16			18.9					0.09		0.02	7.97	7.55	11
30	3.1	1.6		0.11			10.5					0.05		0.02	7.96	7.49	11
31	7.8	2.2		0.14			11.3					0.04		0.01	7.94	7.45	11

TABLE 2.1 PARTICULATE REMOVAL PROFILE

JANUARY 1986

WPOS - Lake Huron Water Supply System

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT $FeCl_3$	COAGULANT PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	3.9			0.19			3					0.03		0.01	7.61	7.38	4
2	2.1			0.14			3					0.03		0.01	7.45	7.18	4
3	1.8			0.18			2					0.02		0.04	7.41	7.23	4
4	2.0			0.22			2					0.01		0.04	7.61	7.59	6
5	2.7			0.21			2					0.02		0.01	7.98	7.72	4
6	4.9			0.23			2					0.03		0.02	7.98	7.56	4
7	6.2			0.28			4					0.03		0.02	7.68	7.47	3
8	4.5			0.28			4					0.02		0.04	8.02	7.71	4
9	2.7			0.28			4					0.02		0.06	7.83	7.42	4
10	2.8			0.26			4					0.04		0.03	7.64	7.44	5
11	2.1			0.27			3					0.04		0.03	7.50	7.29	4
12	2.6			0.31			4					0.05		0.02	7.57	7.30	4
13	2.5			0.26			2					0.01		0.02	7.67	7.34	5
14	2.2			0.24			2					0.03		0.05	7.85	7.53	4
15	1.5			0.19			2					0.04		0.02	7.80	7.52	4

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	FeCl₃ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	1.5			0.22				2				0.01		0.05	7.63	7.17	5
17	1.6			0.22				2				0.03		0.02	7.92	7.42	5
18	1.8			0.24				2				0.02		0.02	7.30	7.09	5
19	3.0			0.24				2				0.01		0.03	7.76	7.21	5
20	10.1			0.28				4				0.01		0.02	7.64	7.17	4
21	10.3			0.25			11.3					0.04		0.04	7.62	7.26	4
22	7.2			0.21			8.9					0.02		0.04	7.77	7.37	5
23	11.1			0.25			10.9					0.04		0.02	7.82	7.58	4
24	4.6			0.25			11.6					0.03		0.01	7.69	7.29	3
25	5.4			0.22			13.9								7.50	7.07	3
26	5.8			0.25			13.0			0.011		0.04		0.02	7.72	7.29	3
27	17.7			0.21			9.6			0.010		0.03		0.01	7.76	7.42	4
28	10.4			0.18			10.8			0.012		0.03		0.01	7.66	7.32	5
29	6.6			0.16			9.1					0.04		0.00	7.53	7.10	4
30	4.9			0.16			9.3					0.04		0.00	7.88	7.44	3
31	4.1			0.17			10.3					0.05		0.00	7.83	7.55	3

(1) DREW 6306A

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT						METAL RES. Fe (mg/L)		pH		TEMP. (°C)
							Alum	FeCl₃	PACl	Filter Aid(1)	Metal Res. Al (mg/L)						
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	2.8			0.14			8.4					0.04		0.02	7.23	6.97	5
2	3.4			0.13			10.5					0.04		0.02	7.87	7.54	5
3	2.0			0.12			10.2					0.03		0.01	7.72	7.58	7
4	1.8			0.11			9.6					0.02		0.01	7.80	7.57	6
5	2.3			0.13			8.1					0.04		0.02	7.75	7.50	6
6	1.9			0.12			9.1					0.03		0.02	7.95	7.72	6
7	2.1			0.14			8.7					0.08		0.01	7.78	7.53	7
8	3.0			0.14			9.4					0.03		0.02	7.74	7.41	7
9	10.8			0.15			15.8					0.01		0.02	7.56	7.37	7
10	16.5			0.17			17.3			0.02		0.04		0.02	7.77	7.39	6
11	22.5			0.16			24.7			0.03		0.04		0.02	7.63	7.35	5
12	15.5			0.11			21.0			0.02		0.04		0.01	7.68	7.35	6
13	9.2			0.14			22.4			0.02		0.06		0.01	7.56	7.35	6
14	16.2			0.18			21.1			0.02		0.05		0.02	7.77	7.49	6
15	5.5			0.16			14.1			0.02		0.06		0.02	7.71	7.43	6

(1) DREW 6306A

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	4.2			0.13			16.1					0.03		0.01	7.72	7.34	7
17	5.6			0.15			16.8					0.02		0.03	7.75	7.44	6
18	6.9			0.18			23.8					0.04		0.02	7.56	7.17	6
19	5.5			0.17			21.4			0.02		0.04			7.75	7.33	6
20	7.5			0.15			20.1			0.02		0.04		0.01	7.76	7.40	8
21	9.0			0.09			21.3			0.02		0.05		0.02	7.72	7.27	7
22	18.8			0.11			21.3			0.02		0.05		0.04	7.65	7.08	7
23	10.3			0.12			18.3			0.02		0.03		0.01	7.65	7.10	6
24	7.4			0.23			20.1			0.02		0.03		0.01	7.92	7.45	7
25	5.9			0.12			18.5			0.02		0.03		0.01	8.04	7.50	8
26	4.1			0.11			17.1			0.02		0.03		0.02	7.89	7.34	8
27	3.3			0.13			16.0			0.02		0.04		0.02	7.91	7.45	8
28	2.7			0.15			10.4			0.02		0.06		0.02	7.77	7.52	8
29	3.0			0.14			12.4					0.05		0.01	7.76	7.31	8
30	2.8			0.20			20.8					0.06		0.01	7.85	7.38	9
31																	

(1) DREW 6306A

TABLE 2.1 PARTICULATE REMOVAL PROFILE

JULY 1986

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT FeCl3	COAGULANT PACl	Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	3.7			0.19			19.3			0.02		0.04		0.00	8.11	7.77	16
2	3.2			0.18			16.9					0.08		0.02	8.40	7.91	16
3	4.3			0.26			17.1					0.10		0.01	8.04	7.68	16
4	3.6			0.26			17.1					0.10		0.02	8.14	7.70	16
5	4.2			0.25			18.2			0.02		0.09		0.01	8.03	7.62	18
6	3.4			0.19			16.7			0.02		0.08		0.02	8.06	7.70	18
7	2.8			0.20			15.4			0.02		0.08		0.01	8.10	7.79	18
8	2.3			0.23			15.7	6		0.02		0.12		0.01	8.29	7.89	18
9	2.2			0.27			13.0	5		0.02		0.13		0.03	8.19	7.86	18
10	2.6			0.31				5		0.02		0.09		0.06	8.32	7.97	18
11	2.6			0.23				7		0.02		0.04		0.01	8.24	7.84	17
12	2.8			0.23				9		0.01		0.03		0.04	8.37	7.98	16
13	3.3			0.24				9		0.02		0.04		0.12	8.37	7.85	16
14	3.6			0.19				8		0.02		0.07		0.02	8.07	7.59	17
15	3.5			0.24				8		0.02		0.05		0.05	7.89	7.59	17

(1) DREW 6306A

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	2.2			0.24			12.6	7		0.02				0.02	7.91	7.55	19
17	3.5			0.34			12.0			0.02		0.12		0.02	7.61	7.40	17
18	3.8			0.34			13.3			0.03		0.08		0.01	8.10	7.72	16
19	2.3			0.25			14.5	9		0.03		0.05		0.02	7.98	7.63	20
20	3.2			0.25			14.5	9		0.03		0.07		0.03	8.06	7.53	18
21	3.5			0.22				8		0.02		0.04		0.03	8.23	7.72	16
22	2.9			0.27				8		0.02		0.02		0.02	8.15	7.63	14
23	3.4			0.25				8		0.02		0.03		0.04	7.96	7.63	16
24	3.5			0.20			15.0	8				0.05		0.04	8.28	7.74	16
25	2.7			0.25			15.0	8				0.08		0.03	8.24	7.73	18
26	2.6			0.23				8				0.08		0.03	8.22	7.83	19
27	2.1			0.22								0.06		0.03	8.19	7.85	18
28	2.2			0.24				8				0.02		0.04	8.05	7.94	19
29	2.6			0.22				8				0.03		0.03	8.10	7.80	20
30	2.5			0.21				7				0.03		0.02	7.98	7.56	21
31	4.3			0.26				8				0.01		0.02	8.28	7.92	20

(1) DREW 6306A

TABLE 2.1 PARTICULATE REMOVAL PROFILE

OCTOBER 1986

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT				Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	Filter Aid(1) mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	2.4			0.11			14.3					0.06		0.01	8.27	7.98	19
2	3.3			0.14			15.8					0.08		0.02	8.21	7.97	19
3	3.8			0.14			16.7					0.08		0.02	7.92	7.77	19
4	7.9			0.19			17.2					0.07		0.02	7.63	7.60	19
5	9.6			0.19			18.6					0.07		0.03	7.51	7.34	18
6	139.6			0.29			30.5	7		0.03		0.07		0.03	7.37	7.28	17
7	81.6			0.27			30.5	8		0.03		0.06		0.03	7.72	7.62	17
8	64.3			0.15			33.0	6		0.03		0.09		0.04	7.82	7.71	16
9	73.0			0.17			23.5					0.04		0.01	7.61	7.44	16
10	28.3			0.23			22.3	7		0.03		0.03		0.03	7.95	7.82	16
11	22.8			0.22			26.4	7		0.03		0.04		0.02	7.83	7.74	16
12	14.8			0.33			30.1	7		0.03		0.06		0.02	7.93	7.65	16
13	12.0			0.70			23.8	4		0.03		0.07		0.03	8.06	7.89	16
14	23.8			0.22			28.7	4		0.03		0.03		0.02	7.56	7.42	16
15	36.3			0.08			32.3			0.03		0.03		0.01	7.60	7.29	16

(1) DREW 6306A

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	18.3			0.20			30.3			0.03		0.03		0.01	7.84	7.76	15
17	13.0			0.17			24.2			0.03		0.04		0.02	7.88	7.78	14
18	15.9			0.18			19.4					0.03		0.01	7.75	7.55	14
19	12.3			0.18			19.0					0.04		0.02	7.38	7.33	14
20	10.8			0.22			34.1					0.05		0.01	7.79	7.72	14
21	8.6			0.17			31.9					0.06		0.03	7.69	7.59	14
22	8.5			0.21			27.0					0.05		0.01	8.00	7.89	14
23	4.7			0.17			22.9					0.04		0.05	7.49	7.42	14
24	5.6			0.17			16.9					0.04		0.00	7.76	7.45	14
25	4.3			0.21			13.7					0.06		0.03	7.79	7.69	14
26	3.6			0.22			14.7			0.02		0.08		0.02	7.84	7.68	14
27	2.7			0.21			16.7			0.02		0.07		0.01	7.76	7.66	14
28	2.2			0.18			18.5					0.05		0.01	7.51	7.46	14
29	3.4			0.20			15.9					0.08		0.01	7.58	7.48	14
30	18.1			0.20			19.7					0.08		0.01	7.72	7.64	14
31	6.1			0.15			16.0					0.05		0.01	7.68	7.56	13

(1) DREW 6306A

TABLE 2.1 PARTICULATE REMOVAL PROFILE

JANUARY 1985

WPOS - Lake Huron Water Supply System

DATE	TURBIDITY (FTU)				COLOUR (TCU)		Alum	COAGULANT $FeCl_3$	PACl	Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	7.0			0.17				4							7.96	7.75	5
2	6.6			0.20				4						0.03	8.16	7.73	5
3	15.0			0.33			14.7	4		0.06				0.01	8.09	7.87	5
4	16.6			0.36			18.7	4		0.06				0.03	7.77	7.62	4
5	13.7			0.22			9.9	4		0.06				0.02	7.89	7.58	4
6	13.9			0.23			8.9	4		0.06				0.02	7.93	7.61	4
7	17.7			0.23			14.4	4		0.01				0.08	7.73	7.40	4
8	23.7			0.21			14.3							0.03	8.03	7.75	4
9	21.8			0.22			15.3							0.04	7.98	7.70	4
10	7.8			0.26			14.6							0.03	7.91	7.61	4
11	7.8			0.19			9.9							0.04	7.79	7.53	4
12	25.4			0.24			14.6			0.04				0.03	8.02	7.74	3
13	14.2			0.15			10.6							0.02	7.85	7.70	3
14	4.8			0.08			9.2					0.04		0.02	7.79	7.49	3
15	20.5			0.29			12.7			0.06				0.02	7.89	7.62	3

(1) SEPARAN NP 10

TABLE 2.1(cont'd.)

JANUARY 1985

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	19.7			0.30			19.9	4		0.06				0.03	7.96	7.42	3
17	13.7			0.21			13.3			0.05				0.02	7.71	7.46	3
18	9.0			0.20			11.2			0.05				0.07	7.78	7.60	3
19	7.5			0.17			10.8							0.04	7.83	7.63	3
20	4.9			0.17			10.6							0.03	7.73	7.50	3
21	10.5			0.17			13.5							0.03	7.95	7.58	3
22	10.8			0.17			11.0							0.04	7.59	7.39	3
23	15.0			0.28			15.4			0.03				0.05	7.83	7.51	3
24	10.7			0.18			13.8			0.06				0.02	7.77	7.61	3
25	7.0			0.16			9.9			0.04				0.04	7.69	7.34	4
26	4.9			0.09			9.8							0.01	7.74	7.36	4
27	4.1			0.11			11.1							0.03	7.88	7.59	4
28	3.5			0.17			12.3					0.06		0.07	7.80	7.53	4
29	3.2			0.22			9.6	4						0.01	7.87	7.71	4
30	3.2			0.27				4						0.03	8.04	7.79	4
31	3.0			0.24				4						0.03	7.58	7.37	4

(1) SEPARAN NP 10

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	COAGULANT $FeCl_3$	COAGULANT PACl	Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	15.8			0.07			14.3			0.012				0.04	7.52	7.53	5
2	21.0			0.08			13.6			0.014				0.03	7.46	7.27	5
3	22.5			0.29			16.8			0.060				0.03	7.57	7.29	6
4	27.3			0.16			23.4			0.009				0.03	7.48	7.31	6
5	15.3			0.10			25.5			0.010				0.03	7.43	7.22	6
6	19.0			0.09			20.0			0.010				0.04	7.29	7.20	6
7	18.5			0.09			19.9			0.010				0.05	7.27	7.14	7
8	15.8			0.10			12.8			0.005				0.02	7.39	7.22	7
9	23.4			0.16			10.4			0.006				0.01	7.51	7.34	7
10	31.7			0.21			18.2			0.015				0.04	7.76	7.71	7
11	24.7			0.18			16.3			0.005		0.02		0.07	7.50	7.23	7
12	25.3			0.18			15.0			0.008				0.03	7.52	7.34	7
13	21.6			0.16			15.0							0.03	7.35	7.16	7
14	21.3			0.27			14.4							0.02	7.59	7.38	8
15	20.9			0.17			16.8			0.007				0.03	7.57	7.34	8

(1) DREW 6306A

TABLE 2.1(cont'd.)

APRIL 1985

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid(1)	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	21.0			0.21			16.6			0.005		0.14		0.01	7.44	7.23	8
17	22.7			0.22			15.0			0.004				0.01	7.46	7.41	8
18	14.6			0.33			15.7			0.005				0.00	7.52	7.34	9
19	8.1			0.12			13.5			0.005				0.02	7.68	7.51	8
20	9.1			0.19			8.9			0.003					7.24	7.10	8
21	10.9			0.21			8.3							0.02	7.52	7.07	8
22	10.3			0.30			10.3							0.03	7.68	7.43	8
23	9.0			0.20			13.3							0.04	7.70	7.49	8
24	7.9			0.23			14.7					0.08		0.01	7.67	7.36	8
25	5.9			0.20			14.7							0.02	8.19	8.09	8
26	4.7			0.18			10.4							0.03	7.91	7.81	8
27	6.9			0.18			16.3							0.02	7.46	7.29	9
28	11.8			0.19			19.2							0.03	7.59	7.36	9
29	2.6			0.27			18.4							0.03	7.48	7.26	9
30	9.9			0.23			19.3							0.02	7.42	7.20	9
31																	

(1) DREW 6306A

DATE	TURBIDITY (FTU)				COLOUR (TCU)		Alum	COAGULANT FeCl3	PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	2.6			0.30				4						0.02	7.85	7.56	15
2	2.7			0.29				4						0.04	7.67	7.32	15
3	2.6			0.34				4						0.02	7.70	7.42	14
4	2.1			0.32				4						0.02	7.88	7.74	16
5	1.3			0.19				4						0.03	7.72	7.35	19
6	1.5			0.17				4						0.02	7.71	7.40	19
7	2.8			0.20				4						0.02	7.80	7.52	19
8	3.0			0.26				4						0.03	7.80	7.37	19
9	2.9			0.26				4						0.02	7.83	7.49	19
10	3.7			0.33				4						0.02	7.87	7.57	20
11	4.3			0.33				8						0.03	7.74	7.43	16
12	3.6			0.32				8						0.04	7.89	7.59	14
13	3.8			0.40				8						0.06	7.98	7.68	14
14	3.4			0.26				10						0.03	7.93	7.66	18
15	2.8			0.23				10						0.02	7.89	7.73	20

TABLE 2.1(cont'd.)

JULY 1985

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	Alum mg/L	FeCl. mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	4.2			0.29				8						0.02	7.76	7.42	20
17	5.7			0.38			13.6							0.02	7.57	7.31	16
18	3.9			0.27			13.5							0.02	7.86	7.52	15
19	4.8			0.31			14.5							0.02	7.91	7.52	15
20	2.9			0.20			13.1							0.03	7.79	7.45	20
21	2.6			0.23			9.2							0.02	7.61	7.37	20
22	9.5			0.36			9.8							0.04	7.88	7.71	20
23	13.9			0.31			16.3							0.01	7.96	7.61	15
24	10.7			0.29			12.3							0.02	7.73	7.21	15
25	3.7			0.20			14.7							0.01	7.74	7.26	18
26	5.3			0.17			9.7							0.02	7.69	7.42	21
27	5.0			0.18			9.9							0.01	7.87	7.44	21
28	3.9			0.19			9.9							0.01	7.72	7.38	21
29	3.3			0.27			8.8							0.02	7.85	7.53	21
30	4.6			0.40			8.8							0.01	7.74	7.40	21
31	5.8			0.40			13.1							0.03	7.73	7.46	17

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT Alum	FeCl₃	PACl	Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Set.	Filter	Treat.	Raw	Treat.	mg/L	mg/L	mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
1	3.6			0.22				2				0.06		0.02	8.05	7.82	18
2	2.0			0.19				2				0.02		0.03	8.09	7.77	17
3	1.3			0.20				2				0.01		0.01	7.96	7.76	17
4	1.1			0.18				2				0.02		0.02	7.95	7.85	17
5	4.4			0.25				2				0.01		0.02	8.09	7.76	17
6	12.4			0.38				4				0.02		0.01	8.18	7.86	16
7	5.5			0.22				4				0.01		0.03	8.15	7.83	16
8	2.1			0.19				4				0.02		0.01	7.93	7.77	16
9	1.5			0.17				2				0.06		0.02	7.95	7.73	15
10	2.6			0.15				2				0.03		0.01	8.05	7.76	15
11	3.2			0.18				2				0.01		0.01	7.97	7.77	15
12	1.4			0.18				2				0.02		0.01	7.99	7.63	15
13	1.3			0.16				2				0.01		0.01	7.86	7.68	15
14	1.5			0.19				2				0.02		0.06	7.95	7.77	16
15	1.4			0.17				2				0.02		0.04	8.15	7.83	15

TABLE 2.1(cont'd.)

OCTOBER 1985

DATE	TURBIDITY (FTU)				COLOUR (TCU)		COAGULANT			Filter Aid	Metal Res. Al (mg/L)		METAL RES. Fe (mg/L)		pH		TEMP. (°C)
	Raw	Sel.	Filter	Treat.	Raw	Treat.	Alum mg/L	$FeCl_3$ mg/L	PACl mg/L	mg/L	Raw	Treat.	Raw	Treat.	Raw	Treat.	
16	4.0			0.22				2				0.03		0.04	8.22	7.82	15
17	2.6			0.18				2				0.03		0.04	8.09	7.76	15
18	1.3			0.15				2				0.03		0.05	7.97	7.76	15
19	1.5			0.16				2				0.02		0.04	7.92	7.52	15
20	1.7			0.20				2				0.01		0.02	8.02	7.61	15
21	2.4			0.28				2				0.01		0.01	8.08	7.87	15
22	1.7			0.24				2				0.02		0.02	7.99	7.81	14
23	1.3			0.21				2				0.02		0.04	7.90	7.67	14
24	1.6			0.22				2				0.02		0.01	7.91	7.67	14
25	2.2			0.20				4				0.01		0.03	7.69	7.45	14
26	1.6			0.19				2				0.01		0.01	7.74	7.45	14
27	2.1			0.32				2				0.01		0.02	7.82	7.63	14
28	9.8			0.30				6				0.02		0.02	7.76	7.55	14
29	4.8			0.34				6				0.02		0.05	8.02	7.68	14
30	3.9			0.24				6				0.02		0.04	8.07	7.71	14
31	3.5			0.25				4				0.02		0.03	7.84	7.52	14

TABLE 3

WATER PLANT OPTIMIZATION STUDY
"DISINFECTION SUMMARY"

06/04/87 (REV. 1)

TABLE 3.0: DISINFECTION SUMMARY

WPOS - Lake Huron Water Supply System

MONTH	CHEMICAL	1987						1986						1985					
		PRE-			POST-			PRE-			POST-			PRE-			POST-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
JAN	Cl_2 Demand																		
	Cl_2 Dosage	0.85	0.24	0.68	1.16	0.50	0.68	0.88	0.49	0.72	1.0	0.51	0.68	0.97	0.55	0.74	0.92	0.53	0.71
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.70	0.36	0.52				0.72	0.39	0.53				0.61	0.48	0.55			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.08	0.89	0.99				1.07	0.94	1.01				1.06	0.89	0.97
	F- Dosage																		
	F- Res.																		
FEB	Cl_2 Demand																		
	Cl_2 Dosage	0.86	0.47	0.64	0.93	0.53	0.67	0.83	0.55	0.66	0.90	0.59	0.75	1.07	0.53	0.70	1.21	0.35	0.58
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.59	0.35	0.50				0.66	0.40	0.49				0.60	0.37	0.51			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.03	0.87	0.96				1.07	0.94	1.01				0.92	0.81	0.89
	F- Dosage																		
	F- Res.																		
MAR	Cl_2 Demand																		
	Cl_2 Dosage	0.96	0.54	0.69	0.96	0.57	0.72	0.93	0.56	0.74	1.6	0.61	0.79	1.3	0.61	0.88	1.02	0.46	0.65
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.61	0.39	0.47				0.65	0.29	0.48				0.78	0.43	0.57			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.03	0.82	0.95				1.07	0.97	1.05				1.06	0.84	0.94
	F- Dosage																		
	F- Res.																		

TABLE 3.0 (cont'd.)

MONTH	CHEMICAL	1987						1986						1985					
		PRE-			POST-			PRE-			POST-			PRE-			POST-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
APR	Cl_2 Demand																		
	Cl_2 Dosage	0.88	0.56	0.68	0.87	0.58	0.70	0.91	0.57	0.79	0.96	0.55	0.71	1.13	0.80	0.88	0.64	0.31	0.53
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.62	0.35	0.48				0.61	0.40	0.52				0.76	0.53	0.62			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.06	0.85	0.97				1.10	0.93	1.00				1.02	0.81	0.95
	F- Dosage																		
	F- Res.																		
MAY	Cl_2 Demand																		
	Cl_2 Dosage	0.81	0.52	0.63	0.96	0.49	0.81				1.6	1.1	1.3	0.93	0.72	0.82	0.85	0.44	0.69
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.70	0.39	0.46										0.64	0.43	0.57			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.02	0.87	0.96				1.07	0.29	1.00				0.99	0.86	0.94
	F- Dosage																		
	F- Res.																		
JUN	Cl_2 Demand																		
	Cl_2 Dosage				1.7	1.1	1.3				1.5	1.2	1.3	0.83	0.62	0.71	0.83	0.63	0.72
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)													0.90	0.46	0.55			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.09	0.91	1.02				1.06	0.86	1.00				1.02	0.50	0.93
	F- Dosage																		
	F- Res.																		

MONTH	CHEMICAL	1987						1986						1985					
		PRE-			POST-			PRE-			POST-			PRE-			POST-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
JUL	Cl_2 Demand																		
	Cl_2 Dosage	0.76	0.22	0.54	1.3	0.70	1.08				1.5	1.1	1.3	0.94	0.53	0.71	0.90	0.68	0.79
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.70	0.41	0.51										0.62	0.46	0.53			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.33	0.98	1.11				1.06	0.94	1.01				1.03	0.88	0.96
	F- Dosage																		
	F- Res.																		
AUG	Cl_2 Demand																		
	Cl_2 Dosage	0.90	0.65	0.71	1.2	0.85	0.99				1.5	1.1	1.3				1.5	0.7	1.2
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.60	0.42	0.52															
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.22	1.06	1.13				1.05	0.95	1.01				1.06	0.89	0.96
	F- Dosage																		
	F- Res.																		
SEP	Cl_2 Demand																		
	Cl_2 Dosage	1.02	0.62	0.73	1.19	0.76	0.95	1.04	0.85	0.94	1.8	0.87	1.3	1.08	0.48	0.82	1.2	0.53	0.81
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.62	0.46	0.53				0.56	0.46	0.51				0.71	0.41	0.56			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.21	0.98	1.11				1.06	0.86	1.01				1.10	0.88	0.98
	F- Dosage																		
	F- Res.																		

TABLE 3.0 (cont'd.)

MONTH	CHEMICAL	1987						1986						1985					
		PRE-			POST-			PRE-			POST-			PRE-			POST-		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
OCT	Cl_2 Demand																		
	Cl_2 Dosage	0.86	0.47	0.74	1.09	0.53	0.84	1.01	0.77	0.88	1.2	0.70	0.92	1.12	0.62	0.79	0.87	0.52	0.72
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.68	0.46	0.54				0.67	0.35	0.54				0.66	0.50	0.59			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.14	0.99	1.05				1.07	0.96	1.03				1.02	0.87	0.96
	F- Dosage																		
	F- Res.																		
NOV	Cl_2 Demand																		
	Cl_2 Dosage	0.74	0.58	0.69	1.4	0.70	1.4	0.95	0.65	0.80	1.04	0.65	0.81	0.75	0.59	0.65	1.7	0.71	1.1
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.54	0.45	0.51				0.63	0.45	0.55				0.57	0.44	0.51			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.4	0.91	1.03				1.09	0.96	1.02				1.10	0.96	1.03
	F- Dosage																		
	F- Res.																		
DEC	Cl_2 Demand																		
	Cl_2 Dosage	0.79	0.56	0.69	1.4	0.63	0.89	0.99	0.52	0.74	0.80	0.52	0.69	0.79	0.14	0.62	1.8	0.61	1.03
	NH_3																		
	SO_2																		
	Cl_2 Res. (Free)	0.67	0.38	0.50				0.64	0.34	0.46				0.69	0.40	0.53			
	Cl_2 Res. (Comb.)																		
	Cl_2 Res. (Total)				1.06	0.92	1.00				1.09	0.88	0.98				1.08	0.94	1.03
	F- Dosage																		
	F- Res.																		

TABLE 3.1: DISINFECTION PROFILE (mg/L) JANUARY 1987

WPOS - Lake Huron Water Supply System

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.72			0.50				0.76					0.97		
2		0.82			0.50				0.65					1.01		
3		0.83			0.52				0.65					1.05		
4		0.85			0.49				0.56					1.03		
5		0.61			0.50				0.65					1.00		
6		0.74			0.45				0.56					0.95		
7		0.71			0.38				0.78					1.01		
8		0.67			0.50				0.78					1.00		
9		0.73			0.61				0.79					1.08		
10		0.77			0.65				0.67					1.02		
11		0.70			0.64				0.58					1.00		
12		0.69			0.53				0.67					1.00		
13		0.66			0.57				0.61					0.99		
14		0.68			0.55				0.68					0.93		
15		0.68							0.68					0.97		
16		0.24			0.70				1.16					1.01		
17		0.28			0.62				0.66					1.03		
18		0.61			0.55				0.50					0.97		
19		0.61			0.50				0.56					0.90		
20		0.67			0.50				0.70					0.95		
21		0.69			0.45				0.75					1.00		
22		0.71			0.51				0.72					1.00		
23		0.64			0.47				0.68					0.97		
24		0.70			0.43				0.75					0.99		
25		0.68			0.48				0.68					1.04		
26		0.68			0.48				0.68					1.03		
27		0.64			0.36				0.65					0.96		
28		0.64			0.57				0.67					1.00		
29		0.61			0.47				0.64					0.89		
30		0.62			0.48				0.60					0.92		
31		0.75			0.54				0.78					1.00		

TABLE 3.1: DISINFECTION PROFILE (mg/L) APRIL 1987

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.67			0.51				0.64					0.96		
2		0.68			0.48				0.70					0.96		
3		0.70			0.59				0.73					0.97		
4		0.74			0.53				0.64					0.96		
5		0.68			0.56				0.70					0.97		
6		0.68			0.40				0.70					0.93		
7		0.68			0.42				0.70					0.91		
8		0.68			0.48				0.70					0.98		
9		0.68			0.51				0.70					1.06		
10		0.68			0.62				0.70					1.05		
11		0.67			0.55				0.58					0.96		
12		0.73			0.50				0.66					0.96		
13		0.71			0.49				0.68					0.92		
14		0.67			0.50				0.73					0.94		
15		0.69			0.51				0.63					0.92		
16		0.73			0.48				0.69					0.91		
17		0.65			0.47				0.65					0.92		
18		0.61			0.52				0.64					1.00		
19		0.77			0.51				0.78					0.96		
20		0.68			0.53				0.88					1.02		
21		0.64			0.51				0.67					0.98		
22		0.60			0.50				0.58					0.95		
23		0.68			0.40				0.70					0.85		
24		0.70			0.37				0.79					0.97		
25		0.65			0.35				0.82					1.02		
26		0.65			0.41				0.83					1.04		
27		0.88			0.48				0.87					1.03		
28		0.56			0.43				0.68					0.99		
29		0.67			0.42				0.75					1.01		
30		0.69			0.40				0.76					0.99		
31																

TABLE 3.1: DISINFECTION PROFILE (mg/L) JULY 1987

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Dos.	Res.
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total		
1									1.3					1.11		
2		0.22			0.41				1.3					1.10		
3		0.59			0.47				1.1					1.06		
4		0.61			0.42				1.0					1.05		
5		0.50			0.70				1.19					1.08		
6		0.68			0.45				1.06					1.04		
7		0.51			0.48				0.91					1.09		
8		0.54			0.44				1.08					1.05		
9		0.61			0.46				1.07					1.05		
10		0.57			0.44				1.10					1.04		
11		0.60			0.43				1.02					1.02		
12		0.46			0.44				0.83					1.04		
13		0.63			0.46				1.14					1.05		
14		0.56			0.44				1.02					1.11		
15		0.43			0.45				0.92					1.06		
16		0.72			0.48				0.96					0.98		
17		0.33			0.43				0.99					1.01		
18									1.3					1.05		
19									1.3					1.14		
20									1.2					1.04		
21									1.3					1.09		
22		0.28			0.54				1.3					1.08		
23		0.76			0.61				1.1					1.16		
24		0.54			0.63				1.08					1.29		
25		0.54			0.62				1.08					1.23		
26		0.54			0.73				1.08					1.23		
27		0.41			0.63				0.70					1.33		
28		0.54			0.55				1.08					1.17		
29		0.65			0.57				1.00					1.21		
30		0.65			0.52				0.96					1.20		
31		0.60			0.56				0.92					1.24		

TABLE 3.1: DISINFECTION PROFILE (mg/L) OCTOBER 1987

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.79			0.59				0.98					1.11		
2		0.80			0.60				0.98					1.09		
3		0.82			0.54				1.04					1.07		
4		0.85			0.58				0.99					1.13		
5		0.86			0.59				1.09					1.14		
6		0.67			0.56				0.82					1.03		
7		0.74			0.50				0.84					1.07		
8		0.56			0.51				0.60					1.06		
9		0.74			0.50				0.84					1.01		
10		0.73			0.47				0.88					1.04		
11		0.76			0.55				0.85					1.07		
12		0.73			0.54				0.86					1.01		
13		0.72			0.55				0.82					1.03		
14		0.73			0.51				0.97					1.11		
15		0.75			0.68				0.88					1.09		
16		0.71			0.53				0.67					1.04		
17		0.72			0.62				0.80					1.09		
18		0.76			0.53				0.77					1.05		
19		0.47			0.58				1.0					1.07		
20		0.74			0.55				0.84					1.05		
21		0.66			0.55				0.75					1.02		
22		0.68			0.55				0.74					1.01		
23		0.56			0.55				0.78					1.02		
24		0.81			0.58				0.85					0.99		
25		0.71			0.53				0.53					1.07		
26		0.65			0.51				0.78					1.03		
27		0.67			0.50				0.80					1.01		
28		0.64			0.50				0.74					1.03		
29		0.69			0.46				0.86					1.00		
30		0.70			0.54				0.79					1.01		
31		0.74			0.46				0.84					1.00		

TABLE 3.1: DISINFECTION PROFILE (mg/L) JANUARY 1986

WPOS - Lake Huron Water Supply System

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.83			0.60				0.65					0.48		
2		0.86			0.72				0.55					1.05		
3		0.77			0.64				0.66					1.07		
4		0.80			0.67				0.60					1.03		
5		0.78			0.61				0.72					1.01		
6		0.64			0.59				0.60					1.00		
7		0.72			0.45				0.68					1.01		
8		0.72			0.44				0.68					1.01		
9		0.72			0.53				0.68					1.03		
10		0.72			0.56				0.68					0.98		
11		0.72			0.55				0.68					1.02		
12		0.72			0.55				0.68					1.06		
13		0.72			0.57				0.68					1.02		
14		0.72			0.55				0.68					0.98		
15		0.72			0.48				0.68					1.03		
16		0.72			0.39				0.68					0.98		
17		0.72			0.49				0.68					0.94		
18		0.68			0.58				0.75					1.02		
19		0.55			0.54				0.68					0.99		
20		0.88			0.52				0.55					1.00		
21		0.65			0.49				0.67					0.96		
22		0.68			0.40				1.00					1.00		
23		0.69			0.46				0.87					1.05		
24		0.65			0.53				0.67					1.05		
25		0.71			0.47				0.69					0.98		
26		0.65			0.40				0.77					0.97		
27		0.49			0.57				0.51					1.01		
28		0.72			0.59				0.68					1.1		
29		0.80			0.58				0.63					1.00		
30		0.86			0.50				0.65					1.00		
31		0.78			0.56				0.75					1.07		

TABLE 3.1: DISINFECTION PROFILE (mg/L·) APRIL 1986

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Dos.	Res.
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total		
1		0.69			0.53				0.63					0.93		
2		0.73			0.44				0.77					0.97		
3		0.68			0.51				0.84					1.01		
4		0.75			0.45				0.75					1.02		
5		0.57			0.48				0.96					1.10		
6		0.76			0.49				0.62					1.03		
7		0.80			0.54				0.61					1.03		
8		0.79			0.46				0.71					0.96		
9		0.83			0.46				0.55					0.95		
10		0.91			0.40				0.75					1.00		
11		0.88			0.46				0.96					1.02		
12		0.80			0.56				0.75					1.00		
13		0.86			0.54				0.89					1.02		
14		0.81			0.49				0.78					0.99		
15		0.81			0.58				0.81					1.01		
16		0.86			0.58				0.77					1.03		
17		0.75			0.61				0.78					1.02		
18		0.85			0.58				0.72					0.96		
19		0.79			0.55				0.71					1.01		
20		0.79			0.58				0.71					1.03		
21		0.79			0.57				0.71					0.99		
22		0.88			0.51				0.81					0.98		
23		0.78			0.54				0.75					1.02		
24		0.83			0.54				0.81					1.06		
25		0.84			0.52				0.76					0.99		
26		0.87			0.46				0.77					1.01		
27		0.83			0.56				0.79					0.98		
28		0.78			0.57				0.74					0.99		
29		0.70			0.52				0.70					0.97		
30									1.1					0.98		
31																

TABLE 3.1: DISINFECTION PROFILE (mg/L) JULY 1986

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1									1.1					0.99		
2									1.4					1.01		
3									1.4					1.06		
4									1.4					1.04		
5									1.3					1.03		
6									1.3					1.02		
7									1.2					0.99		
8									1.5					1.01		
9									1.4					0.99		
10														1.02		
11														1.01		
12									1.4					0.97		
13									1.3					0.94		
14									1.3					0.99		
15									1.3					1.02		
16									1.2					0.99		
17									1.3					0.97		
18									1.4					1.00		
19									1.4					1.00		
20									1.3					1.00		
21									1.4					1.00		
22														1.00		
23														1.01		
24									1.4					1.05		
25									1.4					1.05		
26									1.3					0.99		
27									1.3					0.97		
28									1.4					0.98		
29									1.3					0.99		
30									1.4					1.04		
31									1.4					1.03		

TABLE 3.1: DISINFECTION PROFILE (mg/L)

OCTOBER 1986

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Dos.	Res.
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total		
1		1.01			0.65				0.98					1.07		
2		0.79			0.61				0.70					0.99		
3		0.95			0.65				0.91					1.03		
4		0.92			0.59				0.88					0.98		
5		0.77			0.45				0.83					0.96		
6		0.83			0.35				0.94					0.97		
7		0.84			0.38				0.94					1.02		
8		0.87			0.42				1.2					1.00		
9		0.81			0.37				1.12					1.04		
10		0.96			0.54				1.14					1.07		
11		0.87			0.48				0.81					1.06		
12		0.99			0.60				0.87					1.02		
13		1.02			0.59				0.88					1.02		
14		0.93			0.55				0.91					1.05		
15		0.86			0.56				0.97					1.05		
16		0.89			0.50				1.16					1.06		
17		0.89			0.52				0.92					1.02		
18		0.92			0.54				0.94					1.05		
19		0.87			0.57				0.87					1.04		
20		0.92			0.53				0.92					1.03		
21		0.87			0.54				0.87					1.01		
22		0.86			0.53				0.83					1.04		
23		0.89			0.61				0.83					1.05		
24		0.81			0.54				0.89					1.02		
25		0.93			0.48				0.81					1.00		
26		0.89			0.62				0.92					1.01		
27		0.89			0.67				0.92					1.01		
28		0.86			0.64				0.82					1.05		
29		0.87			0.55				0.83					1.03		
30		0.82			0.50				0.93					1.01		
31		0.85			0.55				0.86					1.06		

TABLE 3.1: DISINFECTION PROFILE (mg/L) JANUARY 1985

WPOS - Lake Huron Water Supply System

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.77			0.55				0.53					1.06		
2		0.80			0.56				0.76					1.05		
3		0.79			0.57				0.73					0.99		
4		0.71			0.48				0.81					1.01		
5		0.71			0.51				0.79					1.01		
6		0.83			0.54				0.86					1.04		
7		0.74			0.55				0.71					1.02		
8		0.74			0.55				0.71					1.04		
9		0.78			0.53				0.78					1.03		
10		0.77			0.57				0.77					1.04		
11		0.77			0.55				0.74					1.00		
12		0.70			0.60				0.90					1.01		
13		0.78			0.59				0.89					1.01		
14		0.74			0.58				0.92					1.03		
15		0.55			0.51				0.68					0.96		
16		0.63			0.54				0.68					0.98		
17		0.69			0.53				0.59					0.94		
18		0.72			0.57				0.54					0.94		
19		0.77			0.55				0.57					0.92		
20		0.97			0.52				0.67					0.90		
21		0.74			0.53				0.71					0.92		
22		0.74			0.61				0.71					0.91		
23		0.74			0.56				0.71					0.89		
24		0.74			0.75				0.71					0.91		
25		0.74			0.48				0.71					0.93		
26		0.74			0.52				0.71					0.91		
27		0.74			0.52				0.71					0.90		
28		0.64			0.55				0.66					0.94		
29		0.73			0.54				0.57					0.93		
30		0.71			0.54				0.63					0.95		
31		0.72			0.58				0.54					0.95		

TABLE 3.1: DISINFECTION PROFILE (mg/L)

APRIL 1985

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Dos.	Res.
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total		
1		0.89			0.62				0.51				1.00			
2		0.89			0.59				0.51				0.93			
3		0.89			0.61				0.51				0.92			
4		0.89			0.53				0.51				0.81			
5		0.89			0.76				0.51				0.98			
6		1.01			0.70				0.57				0.97			
7		1.13			0.70				0.52				1.0			
8		0.80			0.66				0.31				0.99			
9		0.90			0.56				0.55				0.87			
10		0.89			0.56				0.54				0.90			
11		0.83			0.63				0.55				0.90			
12		0.89			0.58				0.50				0.87			
13		0.89			0.53				0.51				0.92			
14		0.89			0.57				0.51				0.92			
15		0.89			0.56				0.51				0.92			
16		0.91			0.63				0.61				0.96			
17		0.84			0.67				0.53				0.97			
18		0.87			0.65				0.55				1.01			
19		0.85			0.59				0.61				1.02			
20		0.85			0.72				0.44				1.01			
21		0.84			0.61				0.60				0.95			
22		0.82			0.65				0.50				1.00			
23		0.88			0.63				0.57				0.98			
24		0.90			0.65				0.63				0.97			
25		0.89			0.59				0.64				0.96			
26		0.86			0.68				0.57				1.01			
27		0.89			0.68				0.51				0.95			
28		0.89			0.65				0.51				0.96			
29		0.89			0.61				0.51				0.93			
30		0.89			0.57				0.51				0.90			
31																

TABLE 3.1: DISINFECTION PROFILE (mg/L) JULY 1985

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.67			0.52				0.71					0.98		
2		0.62			0.50				0.80					0.94		
3		0.67			0.48				0.72					0.92		
4		0.71			0.51				0.79					0.93		
5		0.60			0.53				0.80					0.96		
6		0.64			0.57				0.68					1.02		
7		0.67			0.60				0.76					0.95		
8		0.72			0.56				0.85					1.03		
9		0.76			0.49				0.82					0.99		
10		0.80			0.52				0.77					0.99		
11		0.86			0.60				0.80					1.03		
12		0.94			0.51				0.77					0.98		
13		0.71			0.46				0.90					0.96		
14		0.71			0.47				0.79					0.95		
15		0.71			0.51				0.79					1.00		
16		0.71			0.60				0.84					0.96		
17		0.70			0.49				0.79					0.97		
18		0.75			0.53				0.81					0.95		
19		0.69			0.52				0.82					0.94		
20		0.76			0.57				0.78					0.97		
21		0.78			0.62				0.74					1.00		
22		0.78			0.58				0.79					0.98		
23		0.71			0.56				0.72					0.96		
24		0.77			0.50				0.74					0.91		
25		0.71			0.56				0.79					0.92		
26		0.62			0.50				0.84					0.91		
27		0.78			0.56				0.78					0.97		
28		0.77			0.53				0.87					0.97		
29		0.53			0.46				0.78					0.95		
30		0.67			0.53				0.76					0.97		
31		0.61			0.48				0.77					0.88		

TABLE 3.1: DISINFECTION PROFILE (mg/L)

OCTOBER 1985

DATE	PRE-CHLORINATION							POST-CHLORINATION							FLUORIDE	
	Cl_2		NH_3	SO_2	RESIDUAL Cl_2			Cl_2		NH_3	SO_2	RESIDUAL Cl_2				
	Dem.	Dos.			Free	Comb.	Total	Dem.	Dos.			Free	Comb.	Total	Dos.	Res.
1		0.78			0.51				0.72					0.91		
2		0.90			0.62				0.77					0.96		
3		0.86			0.62				0.76					0.99		
4		0.82			0.58				0.67					0.95		
5		0.93			0.55				0.75					0.92		
6		0.91			0.66				0.68					0.87		
7		0.84			0.66				0.72					0.93		
8		0.71			0.65				0.59					0.98		
9		0.86			0.65				0.70					0.97		
10		0.80			0.63				0.68					0.98		
11		0.79			0.61				0.71					0.95		
12		0.82			0.58				0.76					0.99		
13		1.12			0.71				0.72					1.01		
14		0.87			0.64				0.52					0.97		
15		0.87			0.66				0.81					0.96		
16		0.62			0.52				0.71					1.02		
17		0.72			0.64				0.71					1.01		
18		0.70			0.49				0.73					0.92		
19		0.79			0.57				0.69					0.90		
20		0.75			0.61				0.73					0.97		
21		0.79			0.50				0.73					0.95		
22		0.75			0.53				0.78					0.99		
23		0.63			0.52				0.63					0.93		
24		0.69			0.57				0.64					0.94		
25		0.60			0.60				0.66					0.95		
26		0.78			0.58				0.75					0.98		
27		0.73			0.55				0.70					0.95		
28		0.76			0.56				0.74					0.93		
29		0.67			0.47				0.78					0.91		
30		0.75			0.63				0.85					0.93		
31		0.70			0.54				0.87					0.99		

TABLE 4

WATER PLANT OPTIMIZATION STUDY
"WATER QUALITY SUMMARY"

06/04/87 (REV. 1)

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
GENERAL CHEMISTRY													
Alkalinity (pH 4.9)*	R	86.50					87.30	85.10				83.80	
mg/L	T	81.70					73.30	75.80				76.00	
Ammonia - N Total	R												
mg/L	T												
Calcium - Ca *	R	29.50					28.40	28.80				29.80	
mg/L	T	29.80					28.20	29.60				28.60	
Chloride - Cl	R	6.42	7.12	9.0	6.56	6.38	5.89	6.13	6.43	6.11	6.2	5.9	5.9
mg/L	T												
Colour ACU	R												
TCU	T												
Conductivity	R	214	232	244	229	228	214	217	219	217	213	212	214
µmho/cm	T												
Fluoride - F	R	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10		0.10	0.10	0.11	0.10	0.10	0.10
mg/L	T												
Hardness Total-$CaCO_3$ *	R	103.50					101.00	103.00				106.00	
mg/L	T	103.50					101.00	105.00				102.00	

* MOE DWSP RESULTS

TABLE 4.0 : (Cont'd)

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Magnesium - Mg *	R	7.300	8.750				7.400					7.600	
mg/L	T	7.000	8.600				7.400					7.500	
Nitrate - N	R	0.27	0.50	0.548	0.53	0.399	0.231	0.28	0.265	0.243	0.263	0.302	0.353
mg/L	T												
Nitrite - N	R	0.002	0.005	0.005	0.004	0.003	0.006	0.004	0.004	0.005	0.004	0.007	0.002
mg/L	T												
Nitrogen Total Kjeldahl	R	0.18	0.263	0.242	0.202	0.195	0.406	0.200	0.360	0.353	0.218	0.182	0.263
mg/L	T												
PH	R	7.94	8.05	8.16	8.27	8.46	8.73	8.71	8.70	8.41	8.06	7.94	8.08
	T												
Phosphorus - P Filt.	R	0.003	0.004	0.004	0.001	0.001	< 0.001	0.001	0.002	< 0.001	< 0.001	0.003	0.003
mg/L Total	R	0.008	0.007	0.032	0.005	0.008	0.019	0.006	0.026	0.012	0.005	0.008	0.012
Potassium - K	R												
mg/L	T												
Silica-SiO_2	R												
mg/L	T												

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Sodium - Na	R												
mg/L	T												
Sulphate - SO_4	R												
mg/L	T												
Total Solids	R												
mg/L	T												
Turbidity	R	5.5	14.1	21.7	20.5	8.6	2.0	3.1	9.4	7.2	11.7	14.9	20.9
FTU	T	0.132	0.09	0.10	0.11	0.09	0.18	0.15	0.18	0.16	0.14	0.16	0.13
METALS													
Aluminum - Al	R												
µg/L	T	0.03	0.03	0.03	0.04	0.05	0.08	0.12	0.11	0.08	0.08	0.06	0.04
Cadmium - Cd	R												
µg/L	T												
Chromium - Cr	R												
µg/L	T												

TABLE 4.0 : (Cont'd)

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Copper - Cu	R												
µg/L	T												
Iron - Fe	R												
µg/L	T	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01
Lead - Pb	R												
µg/L	T												
Manganese - Mn	R												
µg/L	T												
Zinc - Zn	R												
µg/L	T												
DISSOLVED GASES													
Carbon Dioxide - CO_2	R												
mg/L	T												
Oxygen - O_2	R												
% Satrn.	T												

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
PURGEABLE ORGANICS *													
Bromoform	R	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
µg/L	T	.000	.000	.000	1.000	.000	.000	.000	.600	.400	.200	.200	.000
Bromodichloromethane	R												
µg/L	T												
Chlorodibromomethane	R	.000	.000	.000	.000	.000			.000	.000	.000	.000	.000
µg/L	T	3.000	4.000	3.000	4.000	4.000	4.800	8.000	4.700	5.100	4.400	4.000	3.800
Chloroform	R	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
µg/L	T	20.000	20.000	22.000	23.000	17.000	25.100	19.000	17.700	17.900	17.900	24.200	22.200
Total Trihalomethane	R	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
µg/L	T	29.000	32.000	35.000	37.000	29.000	40.800	38.000	32.700	33.900	31.900	38.300	37.100
Phenol	R												
µg/L	T												

* MOE DWSP RESULTS

TABLE 4.0 : (Cont'd)

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BACTERIA													
RAW WATER:													
Total Coliform 0-100/100 mL	R	4	4	5	4	4	5	4	3	4	4	4	4
101-5000/100 mL	R								1				
Fecal Coliform 0-10/100 mL	R	2		2	3	4	4	4	4	3	4	4	4
11-500/100 mL	R												
Fecal Streptococcus													
0-1/100 mL	R	1			2	4	4	4	4	3	4	4	4
2-50/100 mL	R												
TREATED WATER:													
Total Coliform Present	T	1		1									
Absent	T	14	16	17	17	14	17	17	15	16	18	16	13
1-4/100 mL	T												

PARAMETER		1987											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TREATED WATER (Cont'd)													
Fecal Coliform Present	T			1			1						
Absent	T												
Fecal Streptococcus													
Present	T			1									
Absent	T	2		1					1				
Standard Plate Count													
0-500/mL	T	1	1	4	4	5	3.	3	5		2	1	3
>500/mL	T												

WPOS - Lake Huron Water Supply System

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
GENERAL CHEMISTRY													
Alkalinity (pH 4.9)	R	83.2							83.2			78.0	
mg/L	T	79.9							77.8			74.8	
Ammonia - N Total	R	0.098	0.035	0.019	0.026	0.046	0.036	0.012	0.002	0.006	0.064	0.113	0.540
mg/L	T												
Calcium - Ca	R												
mg/L	T												
Chloride - Cl	R	6.6	7.6	7.6	7.2	6.3	6.2	6.4	5.9	6.2	6.5	6.0	6.1
mg/L	T												
Colour ACU	R												
TCU	T												
Conductivity	R	223	226	222	234	246	233	228	221	217	228	211	211
µmho/cm	T												
Fluoride - F	R	<0.10		<0.10					<0.10	<0.10	0.06	<0.10	<0.10
mg/L	T	<0.10			<0.10				<0.10	<0.10	<0.10	<0.10	
Hardness Total-$CaCO_3$	R	96							96			92	
mg/L	T	101.5							92			91	

TABLE 4.0 : (Cont'd)

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Magnesium*- Mg	R						7.95	8.10	7.40	7.15	7.50	7.45	6.95
mg/L	T						7.85	7.55	7.30	7.25	7.40	7.40	6.90
Nitrate - N	R	0.35	0.50	0.62	0.58	0.58	0.39	0.33	0.25	0.29	0.41	0.34	0.32
mg/L	T	0.4											
Nitrite - N	R	0.002	0.001	0.003	0.002	0.006	0.006	0.003	0.001	0.003	0.006	0.046	0.010
mg/L	T	<0.01											
Nitrogen Total Kjeldahl	R	0.44	0.38	0.44	0.42	0.38	0.29	0.24	0.20	0.24	0.435	0.50	0.292
mg/L	T												
PH	R	7.70	7.74	7.69	7.74	7.95	7.91	8.13	8.09	7.96	7.76	7.74	7.86
	T	7.37	7.48	7.44	7.39	7.50	7.55	7.74	7.76	7.65	7.62	7.57	7.51
Phosphorus - P Filt.	R	<.001	<.001	0.002	0.002	0.003	0.001	<.001	0.001	0.002	0.002	<.001	<.001
mg/L Total	R	0.020	0.011	0.016	0.012	0.016	0.015	0.010	0.012	0.028	0.038	0.020	0.009
Potassium - K	R												
mg/L	T												
Silica-SiO_2	R												
mg/L	T												

* MOE DWSP RESULTS

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Sodium - Na	R												
mg/L	T												
Sulphate - SO_4	R												
mg/L	T												
Total Solids	R												
mg/L	T												
Turbidity	R	5.0	2.3	5.1	7.1	9.0	4.3	3.1	7.6	11.6	21.3	8.9	5.4
FTU	T	0.23	0.19	0.13	0.14	0.22	0.23	0.24	0.20	0.25	0.21	0.14	0.10
METALS													
Aluminum - Al	R												
µg/L	T	0.03	0.04	0.03	0.04	0.04	0.07	0.09	0.05	0.10	0.06	0.05	0.04
Cadmium - Cd	R												
µg/L	T												
Chromium - Cr	R												
µg/L	T												

TABLE 4.0 • (Cont'd)

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Copper - Cu	R												
µg/L	T												
Iron - Fe	R												
µg/L	T	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.01
Lead - Pb	R												
µg/L	T												
Manganese - Mn	R												
µg/L	T												
Zinc - Zn	R												
µg/L	T												
DISSOLVED GASSES													
Carbon Dioxide - CO_2	R												
mg/L	T												
Oxygen - O_2	R												
% Satrn.	T												

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
PURGEABLE ORGANICS *													
Bromoform	R						.000	.000	.000	.000	.000	.000	.000
µg/L	T						.000	.000	.000	.000	.000	.000	.000
Bromodichloromethane	R												
µg/L	T												
Chlorodibromomethane	R						.000	.000	.000	.000	1.000	.000	.000
µg/L	T						5.000	4.000	5.000	3.000	1.000	.000	3.000
Chloroform	R						.000	.000	.000	.000	27.000	10.000	.000
µg/L	T						31.000	20.000	25.000	25.000	30.000	24.000	22.000
Total Trihalomethane	R						.000	.000	.000	.000	40.000	17.000	.000
µg/L	T						48.000	33.000	41.000	38.000	43.000	35.000	34.000
Phenol	R												
µg/L	T												

* MOE DWSP RESULTS

TABLE 4.0 : (Cont'd)

PARAMETER		1986											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BACTERIA													
RAW WATER:													
Total Coliform 0-100/100 mL	R	18	16	17	17	18	17	18	17	18	4	4	5
101-5000/100 mL	R												
Fecal Coliform 0-10/100 mL	R	18	16	17	17	18	17	18	17	18	4	4	
11-500/100 mL	R												
Fecal Streptococcus													
0-1/100 mL	R	18	16	17	17	18	17	18	17	18	4	4	
2-50/100 mL	R												
TREATED WATER:													
Total Coliform Present	T												
Absent	T	18	16	17	17	18	17	18	17	18	18	16	18
1-4/100 mL	T												

PARAMETER	1986											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TREATED WATER (Cont'd)												
Fecal Coliform Present T												
Absent T												
Fecal Streptococcus												
Present T												
Absent T												
Standard Plate Count												
0-500/mL T												
>500/mL T												

PARAMETER		1985											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
GENERAL CHEMISTRY													
Alkalinity (pH 4.9)	R			97		83		82		83	84	86	81
mg/L	T								80	78	93	81	81
Ammonia - N Total	R	0.063	0.056	0.08	0.071	0.004	0.033	0.036	0.048	0.038	0.045	0.161	0.065
mg/L	T												
Calcium - Ca	R												
mg/L	T												
Chloride - Cl	R	6.0	5.8	7.1	6.3	6.4	6.3	5.0	6.0	5.9	6.0	7.0	6.2
mg/L	T												
Colour ACU	R												
TCU	T												
Conductivity	R	222	228	231	231	222	218	217	221	219	228	229	216
µmho/cm	T												
Fluoride - F	R			0.10				0.10			< 0.10	0.10	< 0.10
mg/L	T										< 0.10	< 0.10	< 0.10
Hardness Total-$CaCO_3$	R			101		100		93		99	96	98	101
mg/L	T								94	100	95	101	103

TABLE 4.0 : (Cont'd)

PARAMETER		1985											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Magnesium - Mg	R												
mg/L	T												
Nitrate - N	R	0.53	0.47	0.76	0.61	0.26	0.39	0.36	0.29	0.29	0.29	0.48	0.40
mg/L	T												
Nitrite - N	R	0.004	0.002	0.01	0.005	0.453	0.004	0.004	0.053	0.012	0.003	0.003	0.003
mg/L	T												
Nitrogen Total Kjeldahl	R	0.40	0.42	0.59	0.61	0.32	0.51	0.39	0.445	0.29	0.418	0.48	0.37
mg/L	T												
PH	R	7.8	7.9	7.7	7.5	7.8	7.8	7.8	8.2	8.1	8.0	8.0	7.8
	T	7.5	7.7	7.5	7.2	7.6	7.5	7.5	7.7	7.7	7.7	7.6	7.6
Phosphorus - P Filt.	R	0.004	0.001	0.010	0.010	0.019	0.002	0.001	0.005	0.002	0.001	0.002	0.001
mg/L Total	R	0.022	0.010	0.040	0.035	0.160	0.019	0.017	0.019	0.010	0.012	0.018	0.019
Potassium - K	R												
mg/L	T												
Silica-SiO_2	R												
mg/L	T												

PARAMETER		1985											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Sodium - Na	R												
mg/L	T												
Sulphate - SO_4	R												
mg/L	T												
Total Solids	R												
mg/L	T												
Turbidity	R	11.2	3.0	14.4	16.7	6.4	3.7	4.3	2.6	2.5	2.9	8.2	19.0
FTU	T	0.21	0.26	0.23	0.19	0.26	0.30	0.28	0.30	0.28	0.22	0.27	0.24
METALS													
Aluminum - Al	R												
µg/L	T	0.05	0.04	0.00	0.08	0.08	0.09		0.07	0.06	0.02	0.04	0.06
Cadmium - Cd	R												
µg/L	T												
Chromium - Cr	R												
µg/L	T												

TABLE 4.0 : (Cont'd)

PARAMETER		1985											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Copper - Cu	R												
µg/L	T												
Iron - Fe	R												
µg/L	T	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.01	0.02
Lead - Pb	R												
µg/L	T												
Manganese - Mn	R												
µg/L	T												
Zinc - Zn	R												
µg/L	T												
DISSOLVED GASSES													
Carbon Dioxide - CO_2	R												
mg/L	T												
Oxygen - O_2	R												
% Satrn.	T												

PARAMETER		1985											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
PURGEABLE ORGANICS													
Bromoform	R												
µg/L	T												
Bromodichloromethane	R												
µg/L	T												
Chlorodibromomethane	R												
µg/L	T												
Chloroform	R												
µg/L	T												
Total Trihalomethane	R												
µg/L	T												
Phenol	R												
µg/L	T												

TABLE 4.0 : (Cont'd)

PARAMETER	1985											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BACTERIA												
RAW WATER:												
Total Coliform 0-100/100 mL R	18	16	17	18	18	16	18	18	17	18	17	18
101-5000/100 mL R												
Fecal Coliform 0-10/100 mL R	18	16	17	18	18	16	18	18	17	18	17	18
11-500/100 mL R												
Fecal Streptococcus												
0-1/100 mL R	18	16	17	18	18	16	18	18	17	18	17	18
2-50/100 mL R												
TREATED WATER:												
Total Coliform Present T												
Absent T	18	16	17	18	18	16	18	18	17	18	17	18
1-4/100 mL T												

PARAMETER	1985											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TREATED WATER (Cont'd)												
Fecal Coliform Present T												
Absent T												
Fecal Streptococcus												
Present T												
Absent T												
Standard Plate Count												
0-500/mL T												
>500/mL T												

PARAMETER		1987			1986			1985		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
GENERAL CHEMISTRY										
Alkalinity (pH 4.9)	R	87.30*	83.80*	85.68*	83.2	78.0	81.5	97	81	85
mg/L	T	81.70*	73.70*	76.80*	77.9	74.8	77.5	93	78	82
Ammonia - N Total	R	0.047	0.010	0.044	0.540	0.002	0.540	0.071	0.004	0.058
mg/L	T									
Calcium - Ca	R	29.80*	28.40*	29.13*						
mg/L	T	29.80*	28.20*	29.05*						
Chloride - Cl	R	9.0	5.9	6.4	7.6	5.9	6.5	7.1	5.0	6.2
mg/L	T									
Colour ACU	R			2						
TCU	T									
Conductivity	R	249	212	222	246	211	225	286	216	228
µmho/cm	T			251						
Fluoride - F	R	0.11	<0.10	<0.10	<0.10	0.06	<0.10	0.10	<0.10	0.10
mg/L	T			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hardness Total-$CaCO_3$	R	106.00*	101.00*	103.38*	96	92	94	101	93	98
mg/L	T	105.00*	101.00*	102.88	101.5	91	94.8	103	94	98

* MOE DWSP RESULTS

TABLE 4.1 : (Cont'd)

PARAMETER		1987			1986			1985		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Magnesium*- Mg	R	8.750	7.300	7.763	8.10	7.15	7.50			
mg/L	T	8.600	7.000	7.625	7.85	6.90	7.34			
Nitrate - N	R	0.548	0.243	0.353	0.62	0.29	0.41	0.76	0.29	0.42
mg/L	T									
Nitrite - N	R	0.007	0.002	0.004	0.046	0.001	0.007	0.45	0.046	0.046
mg/L	T									
Nitrogen Total Kjeldahl	R	0.36	0.18	0.26	0.50	0.20	0.35	0.61	0.29	0.41
mg/L	T									
PH	R	8.73	7.94	8.29	8.13	7.69	7.85	8.2	7.5	7.8
	T	7.95	7.39	7.71	7.76	7.37	7.54	7.7	7.2	7.6
Phosphorus - P Filt.	R	0.004	<0.001	0.002	0.003	<0.001	0.002	0.019	0.001	0.004
mg/L Total	R	0.032	0.005	0.013	0.038	0.009	0.017	0.035	0.010	0.031
Potassium - K	R									
mg/L	T									
Silica-SiO_2	R									
mg/L	T									

* MOE DWSP RESULTS

PARAMETER		1987			1986			1985		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Sodium - Na	R									
mg/L	T									
Sulphate - SO_4	R									
mg/L	T									
Total Solids	R									
mg/L	T									
Turbidity	R	21.7	2.0	11.6	21.3	2.3	7.5	19.0	2.5	7.8
FTU	T	0.18	0.09	0.13	0.25	0.10	0.19	0.30	0.19	0.25
METALS										
Aluminum - Al	R									
µg/L	T	0.12	0.03	0.06	0.10	0.03	0.05	0.08	0.00	0.05
Cadmium - Cd	R									
µg/L	T									
Chromium - Cr	R									
µg/L	T									

TABLE 4.1 : (Cont'd)

PARAMETER		1987			1986			1985		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Copper - Cu	R									
µg/L	T									
Iron - Fe	R									
µg/L	T	0.02	0.01	0.01	0.03	0.01	0.02	0.03	0.01	0.02
Lead - Pb	R									
µg/L	T									
Manganese - Mn	R									
µg/L	T									
Zinc - Zn	R									
µg/L	T									
DISSOLVED GASSES										
Carbon Dioxide - CO_2	R									
mg/L	T									
Oxygen - O_2	R									
% Satrn.	T									

PARAMETER		1987			1986			1985		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
PURGEABLE ORGANICS *										
Bromoform	R	.000	.000	.000	.000	.000	.000			
µg/L	T	1.000	.000	.200	.000	.000	.000			
Bromodichloromethane	R									
µg/L	T									
Chlorodibromomethane	R	.000	.000	.000	1.000	.000	.143			
µg/L	T	8.000	3.000	4.400	5.000	.000	3.000			
Chloroform	R	.000	.000	.000	27.000	.000	5.286			
µg/L	T	25.100	17.000	20.500	31.000	20.000	25.286			
Total Trihalomethane	R	.000	.000	.000	40.000	.000	8.143			
µg/L	T	40.800	29.000	34.558	48.000	33.000	38.857			
Phenol	R									
µg/L	T									

* MOE DWSP RESULTS

TABLE 4.1 : (Cont'd)

PARAMETER	1987			1986			1985		
	Max.	Min.	Avg.*	Max.	Min.	Avg. *	Max.	Min.	Avg.*
BACTERIA									
RAW WATER:									
Total Coliform 0-100/100 mL R			49			169			209
101-5000/100 mL R									
Fecal Coliform 0-10/100 mL R			38			164			209
11-500/100 mL R									
Fecal Streptococcus									
0-1/100 mL R			34			164			209
2-50/100 mL R									
TREATED WATER:									
Total Coliform Present T			2						
Absent T			190			208			209
1-4/100 mL T									

* Total

PARAMETER	1987			1986			1985		
	Max.	Min.	Avg. *	Max.	Min.	Avg.	Max.	Min.	Avg.
TREATED WATER (Cont'd)									
Fecal Coliform Present T			1						
Absent T			4						
Fecal Streptococcus									
Present T									
Absent T									
Standard Plate Count									
0-500/mL T			32						
>500/mL T									

* Total

TABLE 5

WATER PLANT OPTIMIZATION STUDY
"PARTICULATE COUNTING, SUSPENDED SOLIDS AND ALGAE COUNTS"

WPOS - Lake Huron Water Supply System

MONTH		1987		1986		1985	
		Raw	Treated	Raw	Treated	Raw	Treated
Jan.	Max.			1043		478	
	Min.			500		175	
	Avg. *			785		297	
	No. Tests			4		4	
Feb.	Max.			1817		121	
	Min.			245		22	
	Avg. *			892		63	
	No. Tests			4		4	
Mar.	Max.					427	
	Min.					89	
	Avg. *			130		296	
	No. Tests			1		4	
Apr.	Max.						
	Min.						
	Avg. *			20			
	No. Tests			1			
May	Max.						
	Min.						
	Avg. *			15		1999	
	No. Tests			1		1	
June	Max.					1451	
	Min.					469	
	Avg. *			5		1005	
	No. Tests			1		4	

* Geometric Mean for 1986

TABLE 5.0 : (Cont'd) (A.S.U./mL)

MONTH		1987		1986		1985	
		Raw	Treated	Raw	Treated	Raw	Treated
Jul.	Max.					680	
	Min.					269	
	Avg. *			1		452	
	No. Tests			1		5	
Aug.	Max.					1632	
	Min.					247	
	Avg. *			2		742	
	No. Tests			1		4	
Sep.	Max.					859	
	Min.					388	
	Avg. *			7		613	
	No. Tests			1		5	
Oct.	Max.					1640	
	Min.					443	
	Avg. *			15		1023	
	No. Tests			1		4	
Nov.	Max.			474		1552	
	Min.			17		1153	
	Avg. *			191		1320	
	No. Tests			3		4	
Dec.	Max.					1260	
	Min.					538	
	Avg. *			252		917	
	No. Tests			1		4	

* Geometric Mean for 1986

TABLE 6

WATER PLANT OPTIMIZATION STUDY
"BACTERIOLOGICAL TESTING"

TABLE 6.0: BACTERIOLOGICAL TESTING 1987

MONTH	R/T	TOTAL COLIFORM					FECAL COLIFORM					FECAL STREPTOCOCCUS			
		Absent	1-5	6-100	101-5000	>5000	Absent*	1-5	6-10	11-500	>500	Absent*	1	2-50	>50
JAN	R			4					2				1		
	T	14										2/			
FEB	R			4											
	T	16													
MAR	R			5					2						
	T	17					/1					1/1			
APR	R			4					3				2		
	T	17													
MAY	R			4					4				4		
	T	14													
JUN	R			5					4				4		
	T	17					/1								
JUL	R			4					4				4		
	T	17													
AUG	R			3	1				4				4		
	T	15										1/			
SEP	R			4					4				3		
	T	16													
OCT	R			4					4				4		
	T	18													
NOV	R			4					4				4		
	T	16													
DEC	R			4					4				4		
	T	13													

NOTE: All results are for 100 mL samples. Tests carried out at MOE lab, Resources Road.

R = Raw; T = Treated

* Absent/Present

TABLE 6.1: BACTERIOLOGICAL TESTING 1986

MONTH	R/T	TOTAL COLIFORM					FECAL COLIFORM					FECAL STREPTOCOCCUS			
		Absent	1-5	6-100	101-5000	>5000	Absent	1-5	6-10	11-500	>500	Absent	1	2-50	>50
JAN	R			18					18				18		
	T	18													
FEB	R			16					16				16		
	T	16													
MAR	R			17					17				17		
	T	17													
APR	R			17					17				17		
	T	17													
MAY	R			18					18				18		
	T	18													
JUN	R			17					17				17		
	T	17													
JUL	R			18					18				18		
	T	18													
AUG	R			17					17				17		
	T	17													
SEP	R			18					18				18		
	T	18													
OCT	R			4					4				4		
	T	18													
NOV	R			4					4				4		
	T	16													
DEC	R			5											
	T	18													

NOTE: All results are for 100 mL samples. Tests carried out at MOE lab, Resources Road.

R = Raw; T = Treated

TABLE 6.2: BACTERIOLOGICAL TESTING 1985

MONTH	R/T	TOTAL COLIFORM					FECAL COLIFORM					FECAL STREPTOCOCCUS			
		Absent	1-5	6-100	101-5000	>5000	Absent	1-5	6-10	11-500	>500	Absent	1	2-50	>50
JAN	R			18					18				18		
	T	18													
FEB	R			16					16				16		
	T	16													
MAR	R			17					17				17		
	T	17													
APR	R			18					18				18		
	T	18													
MAY	R			18					18				18		
	T	18													
JUN	R			16					16				16		
	T	16													
JUL	R			18					18				18		
	T	18													
AUG	R			18					18				18		
	T	18													
SEP	R			17					17				17		
	T	17													
OCT	R			18					18				18		
	T	18													
NOV	R			17					17				17		
	T	17													
DEC	R			18					18				18		
	T	18													

NOTE: All results are for 100 mL samples. Tests carried out at MOE lab, Resources Road.

R = Raw; T = Treated

TABLE 7

WATER PLANT OPTIMIZATION STUDY
"ONTARIO DRINKING WATER OBJECTIVES
EXCEEDANCE SUMMARY"

06/04/87 (REV. 1)

TABLE 7.0: EXCEEDANCE SUMMARY
ONTARIO DRINKING WATER OBJECTIVES
INCLUDING ALUMINUM (TREATED WATER AT PLANT)

DATE	PARAMETER	MEASURED PARAMETER	OBJECTIVE LIMIT

Note None of the parameters measured during 1985 to 1987 exceeded the Ontario Drinking Water Objectives.

APPENDIX D

TERMS OF REFERENCE

Purpose

To review the present conditions and determine an optimum treatment strategy for contaminant removal at the plant, with emphasis on particulate materials and disinfection processes.

Work Tasks

1. Receive an information package from the MOE. Review the information provided and meet with the MOE staff, if required, to discuss the project.

2. Document the quality and quantity of raw and treated waters.

3. Define the present treatment processes and operating procedures. Prepare a progress report on Works Tasks 1-3 for the Project Committee.

4. Assess the methods of efficient particulate removal which would utilize the present major capital works of the plant. Evaluate the particulate removal efficiency and sensitivity of operation, assuming optimum performance of the plant.

5. Assess current disinfection practices and possible improvement methods.

6. Describe possible short and long-term process modifications to obtain optimum disinfection and contaminant removal.

7. Prepare a draft report for the project committee's review.

8. Prepare the final report.

1. RECEIVE AN INFORMATION PACKAGE FROM THE MOE. REVIEW THE INFORMATION PROVIDED AND MEET WITH THE MOE STAFF, IF REQUIRED, TO DISCUSS THE PROJECT.

Elements of Work

(a) Receive an information package from the MOE concerning the plant and the study. This package includes a general terms of reference, a general table of contents for organizing the study in a manner consistent with other plant reports, the WPOS reporting tables and a copy of Ontario Drinking Water Objectives.

(b) Review the information and prepare for a meeting to initiate the work on the project, including preparation of a schedule of manpower and staff committments.

(c) Meet with the MOE to discuss the available data, the terms of reference, and the project staff and work schedule. If a consultant is carrying out more than one study it may not be necessary to meet with the MOE at the start of each study.

2. DOCUMENT THE QUALITY AND QUANTITY OF RAW AND TREATED WATERS.

Elements of Work

(a) Prepare a monthly summary of maximum, minimum, and average flows for the last three consecutive years (Table 1.0). Address any discrepancies which exist between raw and treated flow rates.

(b) Based on the above, briefly review and tabulate for the last three years, the monthly maximum, minimum, and average per capita flow for the total population served by the plant (Table 1.1). Compare the plant data with typical per capita flows for the local region. Indicate major consumers who may influence the figures.

(c) Document the methods of measuring the raw and treated water flow rates.

(d) Summarize, for the last three consecutive years, where available, the raw and treated water; turbidity, colour, residual aluminum/iron, pH, temperature and treatment chemical dosages (other than disinfection and fluoridation). The summary should indicate the monthly daily average and maximum and minimum day (Table 2.0).

For the same three year period, tabulate also the daily average for the typical seasonal months of January, April, July and October as well as other months in which problems with particulate removal occurred (Tables 2). Document enough data to define and evaluate those problems.

Record other data, such as particulate counting, suspended solids, and algae counting (Table 5.0) which could reflect on particulate removal efficiency.

Document the source and methods used in determining all information.

A comparison should be made between the plant and outside laboratory information to ascertain the relative validity of the data. For plant data, emphasis should be given to plant laboratory tests rather than continuous process control instruments.

(e) Summarize for the last three consecutive years, where available, the disinfectant demand, dosages (including all disinfection related chemicals and residuals) for all application points as well as fluoridation dosage and residual. The summary should indicate the monthly daily average and maximum and minimum day (Table 3.0).

For the same three year period, tabulate (Tables 3) the daily average for the typical seasonal months of January, April, July and October as well as other months in which problems with chlorine residuals and/or positive bacterial tests identified in Table 6. Document enough data to define and evaluate those problems.

Document the methods of dosage evaluation and residual measurements, and establish the validity of the data provided.

(f) Prepare a summary, based on at least three years of data, of the raw and treated water quality testing data for physical, microbiological, radiological, and chemical water quality information (Table 4). Document as much data as is needed to show possible seasonal trends in water quality. Where possible, show corresponding sets of raw and treated water quality information.

Document the source and methods used in determining all water quality information and establish the validity of the data, comparing plant and outside laboratory data.

(g) Tabulate, for the last three consecutive years, the raw and treated water bacterial test information at the plant (Table 6).

Document the source and methods used for all data provided.

(h) Document the water sampling systems (source, pump, line-material and size, vertical rise velocity sampling location) used in the plant (similar to DWSP Questionnaire in Appendix A).

(i) Prepare a summary of inplant testing including Test, Sampling Point, Testing Frequency, Reporting Frequency, Testing Instrumentation including calibration.

(j) Identify other water quality concerns, not related to particulate removal or disinfection, which should be considered as part of the assessment phase of this evaluation program.

3. DEFINE THE PRESENT TREATMENT PROCESSES AND OPERATING PROCEDURES. PREPARE A PROGRESS REPORT ON WORK TASKS 1-3 (8 COPIES), FOR THE PROJECT COMMITTEE.

Elements of Work

(a) Where drawings are available, assemble sufficient record drawings of a reduced size, to document the general site layout and the interrelationship of major plant components. If available, include a process and piping diagram (PAPD) of the plant operations.

(b) Prepare a simplified block schematic of all major plant components including chemical systems and indicating design parameters. Appendix B is an example of the required standard schematic.

(c) Prepare a photographic record of the plant facilities, illustrating all of the major plant components and chemical feed systems. The record should include approximately 30-40 coloured (9 cm x 12 cm) (or 10 cm x 15 cm) prints, suitably labelled. The progress and draft reports may include photocopies in lieu of the prints.

(d) Tabulate the design parameters for all the major plant components, with emphasis on the process operations, including chemical feeds. This information, as a minimum, must be consistent with the DWSP Questionnaire (Appendix A) and must be confirmed and verified by field observations. The design parameters should be evaluated at design, rated and actual operational flows.

(e) Prepare a summary of how the plant is operated, including chemical dosage control, such as jar testing information, filter backwashing procedures and initiation, and pumping and flow control.

(f) Document all reported and other apparent problems in plant operations and/or in the distribution system related to water quality. In addition list the health related parameters which exceed the Ontario Drinking Water Objectives (Table 7).

(g) Submit 8 copies of the progress report to the Prime Consultant for distribution to the Project Committee.

4. ASSESS THE METHODS OF EFFICIENT PARTICULATE REMOVAL WHICH WOULD UTILIZE THE PRESENT MAJOR CAPITAL WORKS OF THE PLANT. EVALUATE THE PARTICULATE REMOVAL EFFICIENCY AND SENSITIVITY OF OPERATION, ASSUMING OPTIMUM PERFORMANCE OF THE PLANT.

Elements of Work

(a) Assess the validity and implication of all information relating to particulate removal provided in Work Tasks 1 and 2 with emphasis on method, metering and sampling, etc.

(b) Using information provided in Work Tasks 1, 2 and 3 evaluate the plant's particulate removal efficiency. The basis of minimum particulate removal should be 1.0 F.t.u. It should, however, be recognized that it is desirable to strive for an operational level which is as low as is achievable.

(c) Conduct an evaluation of possible optimum performance alternatives. Include jar testing using established industry practice.

(d) Evaluate the feasibility of optimum removal using the existing plant capital works. This evaluation should consider the worst case water quality conditions, even though field testing data may not be available during the initial phase of the study (see Work Task 7).

(e) Describe the operational procedures, management strategies, and equipment required for various feasible alternatives. Estimate chemical dosages, level of operational expertise, and sensitivity of operation of the alternatives.

5. ASSESS CURRENT DISINFECTION PRACTICES AND POSSIBLE IMPROVEMENT METHODS.

Elements of Work

(a) Assess the validity and implication of all information relating to disinfection provided in Work Tasks 1, 2 and 3 with emphasis on method, metering and sampling etc.

(b) Using the information provided in Work Tasks 1, 2 and 3 evaluate the plant's ability to disinfect the water. The basis of minimum disinfection should be to ensure a water quality as described in the Ontario Drinking Water Objectives.

(c) Conduct an evaluation of possible optimum disinfection procedures for the plant, with consideration also given to the reduction of chlorinated by-products in the treated water.

(d) Evaluate the feasibility of the various alternatives using the existing plant capital works.

(e) Assess the relative merits of the alternatives. Describe the operational procedures, management strategies, and equipment required for the feasible alternatives. Estimate chemical dosages, level of operational expertise, and sensitivity of operation for the alternatives.

6. DESCRIBE POSSIBLE SHORT AND LONG-TERM PROCESS MODIFICATIONS TO OBTAIN OPTIMUM DISINFECTION AND CONTAMINANT REMOVAL.

Elements of Work

(a) Prepare a list of modifications which should be considered for detailed implementation evaluation. Provide an estimated cost and possible schedule for implementation for each of the proposed modifications.

It is not the purpose of this study to provide a detailed implementation scheme for plant rehabilitation. It is, however, necessary to scope the feasible short and long-term process modifications required to achieve optimum disinfection and contaminant removals.

(b) Incorporate (a) above in the draft report.

7. PREPARE A DRAFT REPORT FOR THE PROJECT COMMITTEE'S REVIEW. (8 COPIES).

Elements of Work

(a) The report must include all information for Work Tasks 1-6.

The information must be organized and presented in a logical and co-ordinated fashion. A general table of contents (Appendix C) is provided for organizing the material in a manner consistent with other plant reports.

Submit the draft report for review by the Project Committee.

(b) Meet with the Project Committee on site at least one week after submission of the report.

(c) Prepare a separate letter report containing recommendation(s) concerning the need for additional field testing to cover quality conditions not available during the period of this study. The Project Committee may decide to delay completion of the final report until field data can be obtained to confirm the predictions of performance for the worst case water conditions.

8. PREPARE THE FINAL REPORT.

Elements of Work

(a) Conduct additional field testing if required. Discuss the implementations of the results with the Project Committee if the results differ from the predicted performance.

(b) Amend the report as per review comments, incorporating additional field data if required.

(c) Submit 25 copies of the final reports (including the colour photographs) to the MOE for distribution.